NONRESIDENT TRAINING COURSE

Hull Maintenance Technician

NAVEDTRA 14119

PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this self-study course is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

COURSE OVERVIEW: In completing this nonresident training course, you will demonstrate an understanding of course materials by correctly answering questions on the following: safety; ship repair; woodworking cuts and joints; small boat repair and deck coverings; tools and equipment; metallurgy; introduction to cutting and welding; oxyacetylene cutting and welding; brazing and braze welding; metal-arc welding and cutting; nondestructive tests and inspection of welds; sheet metal layout and fabrication; structural steel fabrication; shop mathematics; piping systems; piping system repairs; and sewage systems.

THE COURSE: This self-study course is organized into subject matter areas, each containing learning objectives to help you determine what you should learn along with text and illustrations to help you understand the information.   The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards*, NAVPERS 18068.

THE QUESTIONS: The questions that appear in this course are designed to help you understand the material in the text.

VALUE: In completing this course, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

CONTENTS

CHAPTER 1

SAFETY

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

● *Identify the basic safety requirements, and how the role of responsibility starts with you.*

● *Identify various sources of information regarding safety.*

● *Identify various warning signs, placards, tags, and labels.*

● *Describe the safety precautions to be followed when working on or with electrical welding equipment.*

● *Describe the safety procedures to follow when working with chemicals and solvents.*

● *Describe the safety procedures to follow when working on or with various tools, equipment, and machinery.*

● *Describe the safety procedure, and precautions to follow before and after hotwork operations.*

● *Describe the safety procedures to follow when performing cutting operations.*

● *Describe the Navy's Hearing Conservation and Noise Abatement programs.*

● *Describe the Navy's Heat Stress Control Program.*

INTRODUCTION

It is Navy policy to provide a safe and healthy work place for all personnel. These conditions can be ensured through an aggressive and comprehensive occupational safety and health program fully endorsed by the Secretary of the Navy and implemented through the appropriate chain of command. Safety begins with you.

The material discussed in this chapter stresses the importance of observing standard safety precautions and procedures. As a Hull Technician, you will be working with different types of equipment, such as electrical welding equipment. All electrical equipment is hazardous; therefore, all safety precautions must be strictly observed. The primary goals of an effective safety program are to protect personnel and material and to ensure that unsafe equipment operations do not occur. As a petty officer or chief petty officer, you have the responsibility to recognize unsafe conditions and to take appropriate actions to correct any discrepancies.

A number of safety precautions that are likely to concern HTs at one time or another are listed in this chapter. You need to observe all of these precautions. The purpose of this chapter is not to teach safety but to stress emphatically to all personnel that to work safely and to be safety conscious at all times is as much a part of their trade as may be any of its finer secrets or skills and to keep forever in mind, in the execution of their duties, this one simple slogan: WORK SAFELY.

SAFETY RESPONSIBILITIES

All individuals have the responsibility to understand and observe safety standards and regulations that are established for the prevention of injury to themselves and other people and damage to property and equipment. As an individual, you have a responsibility to yourself and to your shipmates to do your part in preventing mishaps. As a petty officer or chief petty officer, you have the responsibility of setting a good example; you cannot ignore safety regulations and expect others to follow them.

Personnel should always observe the following safety practices:

● Observe all posted operating instructions and safety precautions.

● Report any unsafe condition or any equipment or material deficiency you think might be unsafe.

● Warn others of hazards and the consequences of their failing to observe safety precautions.

● Wear or use approved protective clothing or protective equipment.

● Report any injury or evidence of impaired health that occurs during your work or duty to your supervisor.

● Exercise reasonable caution as appropriate to the situation in the event of an emergency or other unforseen hazardous conditions.

● Inspect equipment and associated attachments for damage before using the equipment. Be sure the equipment is suited for the job.

Lessons learned from many industrial mishaps that have been investigated and studied have been compiled into easily understandable booklets and pamphlets published to propagate and market safety awareness and familiarity with various rules and regulations. Also, many safety devices and aides of all types have been developed to save lives and to provide a means for avoiding mishaps. However, all of the safety literature, devices, or aides that have been developed thus far and those that will be developed in the future can only help the one real instrument of safety play its part. That one real instrument of safety is a careful and safety-conscious worker.

All personnel should make it a habit to observe the following "ten commandments of safety."

1. LEARN the safe way to do your job before you start.

2. THINK safety and ACT safely at all times.

3. OBEY safety rules and regulations—they are for your protection.

4. WEAR proper clothing and personal protective equipment (PPE).

5. CONDUCT yourself properly at all times—horseplay is prohibited.

6. OPERATE only the equipment you are authorized to use.

7. INSPECT tools and equipment for safe condition before starting work.

8. ADVISE your superior promptly of any unsafe conditions or practice.

9. REPORT any injury immediately to your superior.

10. SUPPORT your safety program and take an active part in safety meetings.

In addition to these rules, there are other good work habits that will help you perform your job more efficiently as well as safely.

Remember: Mishaps seldom just happen; they are caused. Another point to remember is to never let familiarity breed contempt. Most mishaps could have been prevented had the individuals involved heeded the appropriate safety precautions. Preventing mishaps that are avoidable will help you in the Navy and possibly determine whether or not you survive.

PROMOTING SAFETY

Promoting safety will require you to become safety conscious to the point that you automatically consider safety in every job or operation. By safety reminders

and your personal example, you pass this safety consciousness on to other personnel.

ENFORCING SAFETY

Safety precautions, as all rules, laws, or regulations, must be enforced. It is your duty to take appropriate action any time you see someone disregarding a safety precaution. You should ensure that all jobs are done according to applicable safety precautions.

Doing a job the safe way in some cases may take a little longer or be a little more inconvenient, however, there is no doubt as to the importance of doing it this way.

SOURCES OF SAFETY INFORMATION

To be an effective petty officer and supervisor, you should become familiar with the types of safety programs implemented throughout the Navy. You should also be familiar with all safety directives and precautions concerning your division. Safety instructions vary from command to command. This makes it impossible to give you a complete listing of manuals and instructions with which you should be familiar. Besides studying the information on safety described in this chapter and throughout this training manual, you should read and have knowledge of the safety information in the following references:

● *Standard Organization and Regulations of the U. S. Navy,* OPNAVINST 3120.32B, chapter 7—Outlines the safety program and the safety organization.

● *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat,* OPNAVINST 500.19C—Provides general shipboard safety precautions and specific occupational health program guidance.

● *Navy Occupational Safety and Health (NAVOSH) Program Manual,* OPNAVINST 5100.23C—Encompasses all safety disciplines, such as systems safety, aviation safety, weapons/explosives safety, off-duty safety (recreation, public, and traffic), and occupational safety and occupational health.

● *Naval Ships' Technical Manual,* chapter 074—Provides general welding safety precautions.

Personnel are also advised and informed on mishap prevention through the following periodicals:

Fathom magazine, the afloat safety review, is published bimonthly for the professional benefit of all hands by the Navy Safety Center. *Fathom* presents the most accurate information currently available on the subject of shipboard mishap prevention.

Ships' Safety Bulletin is published monthly by the Navy Safety Center. This bulletin contains articles on shipboard safety problems, trends, mishap briefs, and statistics.

Deckplate magazine is published bimonthly by the Naval Sea Systems Command. This magazine contains information on the design, construction, conversion, operation, maintenance, and repair of naval vessels and their equipment. It also contains articles on safety hazards and their prevention.

Flash, a monthly mishap prevention bulletin, provides a summary of research from selected reports of submarine hazards to assist in the prevention program. It is intended to give advance coverage of safety-related information while reducing individual reading time.

These publications, as well as notices and instructions distributed by the cognizant bureaus, make excellent reference materials. When these publications are available, you should read them and incorporate them into your training program.

Other sources of safety information that you will be dealing with on a day-to-day basis in your work as a Hull Technician are manufacturers' technical manuals and PMS maintenance requirement cards (MRCs).

These are not all of the safety resources that are available to you. However, these sources give you a good starting point from which you can expand your knowledge of safety procedures. The *Naval Safety Supervisor,* NAVEDTRA 12971, is also a very good resource for strengthening your awareness of safety procedures.

WARNING SIGNS, PLACARDS, TAGS, LABELS, AND MARKINGS

Warning signs, placards, tags, labels, and suitable guards/markings should be provided to prevent personnel from coming into accidental contact with dangerous equipment; for warning personnel of the possible presence of airborne contaminants as a result of grinding operations; and for warning personnel of other dangers that may cause injury to them. Equipment installations should not be considered complete until appropriate warning signs have been posted in full view of operating and maintenance personnel.

Warning signs (red/white) and caution signs (yellow/black) should be located in an area where known hazardous conditions exist or may exist. Some of the areas that are hazardous aboard ship include workshops, pump rooms, and machinery spaces. However, hazards may be encountered anywhere aboard ship.

Signs designating an entire space as hazardous must be posted at eye level or above in full and clear view of entering personnel. Signs designating a specific piece of equipment as hazardous must be posted on or near equipment (in full view of the equipment operator) that is particularly dangerous.

Warning placards (fig. l-l) should be located on the door to the entrance of any space where noise levels are consistently high, requiring single- or double-hearing protection. A warning placard should also be displayed on all portable equipment capable of emitting noise in excess of 84 dB(A) when operated. Remember that the messages are aimed at YOU. It is your responsibility to "read and heed."

Tags and labels are used in the Navy to identify a defective piece of equipment or instrument. Tags and labels are also used to ensure the safety of personnel and to prevent improper operation of equipment. They will be posted according to authorized procedures and must not be removed or violated without proper authorization and adequate knowledge of the consequences.

The use of tags and labels is not a substitute for other safety measures, such as locking valves or removing fuses from a fuse panel. Also, tags or labels associated with tag-out procedures must never be used for anything other than their intended purpose.

Figure 1-1.—A warning placard.

Remember, once a tag or label is used, it should only be removed by signed authorization of the authorizing officer. You should always follow your command's procedures for logging and recording tag-out actions.

Markings consisting of paint or tape are used to designate safe traffic lanes, operator caution areas, operator working areas, and observer safe areas.

Safe traffic lanes are designated in workshops. These lanes start and stop at all exits and entrances for workshops and are marked by continuous white lines, 3 inches wide, painted on the deck.

Operator caution areas, operator working areas, and observer safe areas are designated for each equipment working area deemed hazardous. Operator caution areas are marked by a continuous yellow tine, 3 inches wide, outlining the caution area. Operator work areas are marked by painting the deck yellow in areas where it is safe for an operator of machinery or equipment. The outer perimeter of this area is designated by alternate black and yellow lines, or checkerboard pattern, 3 inches wide. Observer safe areas are designated as all areas outside of this perimeter and are the normal color of the deck within the space.

Eye hazardous areas are marked with a black and yellow checkerboard, or chevron, pattern and a label plate made up of black letters on a yellow background that reads: "WARNING EYE HAZARD."

SAFETY EQUIPMENT

Safety equipment is for you. It will protect you from injury and may possibly save your life. Some of the more common types of safety equipment for your personal protection are described in the following paragraphs.

EYE PROTECTION

Proper eye protection is of the highest importance for all personnel. Eye protection is necessary because of hazards caused by infrared and ultraviolet radiation or by flying objects such as sparks, globules of molten metal, or chipped concrete and wood. These hazards are always present during welding, cutting, soldering, chipping, grinding, and a variety of other operations. It is absolutely necessary for you to use eye protection such as helmets, face shields, goggles, and safety glasses during eye-hazard operations. Appropriate use of goggles will limit eye hazards. Some goggles have plastic windows that resist shattering upon impact. Others are designed to limit harmful infrared and ultraviolet radiation from arcs or flames by use of appropriate filter lenses. Remember, eye damage can be extremely painful. Protect your eyes.

HEARING PROTECTION

Proper hearing protection is a must when working with or around certain types of power tools. Some tools are capable of producing dangerously high noise levels which, if ignored, can result in serious hearing loss or injury. You should use hearing protection regularly. Examples of hearing protection are aural hearing protectors, single-flanged earplugs, double-flanged earplugs, triple-flanged earplugs, and foam earplugs.

SAFETY SHOES/BOOTS

Safety shoes/boots protect and prevent injury or loss of toes. Some safety shoes are designed to limit damage to your toes or feet from falling objects. A steel plate is placed in the toe area of such shoes so that your toes are not crushed if an object falls on them. Other safety shoes are designed for use where danger from sparking could cause an explosion. Such danger is minimized by elimination of all metallic nails and eyelets and the use of soles that do not cause static electricity. Examples of safety shoes are boondockers, high-steel toe, and molder boots.

RESPIRATORS AND MASKS

Respirators and masks protect personnel from the inhalation of many toxic materials. The wearing of a respirator is required when performing grinding, welding, brazing, and wood operations. It is also required when you are exposed to high concentrations of hazardous vapors or fumes. Respirators and masks provide protection against aerosols, dusts, fumes, and vapors. Some respirators are disposable and others are reusable. A filter or disposable respirator protects against dust; and the reusable chemical cartridge type of air-purifying respirator protects against gaseous contaminants. Particle masks, air line hose masks, and vapor masks are also reusable.

SAFETY HAZARDS AND PRECAUTIONS

HTs perform plan, supervise, and perform tasks necessary for fabrication, installation, and repair of all types of shipboard structures, plumbing, and piping systems. This includes performing welding, cutting, brazing, and grinding operations. Because of this, HTs must be aware of the general and specific safety precautions involved in their work. The following paragraphs will discuss some of the safety hazards and precautions that you should be familiar with.

MACHINE/EQUIPMENT SAFETY

Before using any machine or piece of equipment, you must be familiar with all safety precautions pertaining to its operation. Carelessness around any moving machinery is extremely dangerous. When moving machinery is equipped with sharp cutting tools, the dangers are greatly increased. The following list includes some of the more general safety precautions for machines/equipment. Specific safety and operating precautions should be posted in plain sight on or by every machine.

—Before operating a machine, make sure there is plenty of light to work by.

—Do not distract the attention of a machine operator.

—Do not lean against any machine that is in motion. Keep clear of all gears, belts, and other moving parts. Never remove the guards from any part of an operating machine.

—Never start a machine unless you are thoroughly familiar with its operation.

—Do not attempt to clean, adjust, or repair a machine while it is in motion. Shut off the power supply to the machine. NEVER attempt to clean running gears.

—PROTECT YOUR EYES. Do not hold your head too close to the cutting tool-flying bits of metal or scale may get into your eyes. Always wear goggles when there is any danger of flying particles getting in your eyes; for example, when using a grinding or drilling machine.

—PROTECT YOUR HEARING. Always wear appropriate hearing protection. Either aural hearing protectors (mickey mouse ears) or ear plugs will reduce the noise from running machinery. Prolonged exposure may damage your hearing.

—Keep your fingers away from the cutting edges when the machine is in operation; otherwise, you could lose some fingers.

—Do not wear gloves or loosely hanging clothes. They can be caught by moving parts of the shop machinery and cause serious injuries. Keep your sleeves rolled down and buttoned up tightly Do not wear neckties or loose neckerchiefs. If clothing becomes caught in a machine, shut off the power immediately.

—When using portable electric equipment around machine tools, take special care so that electrical cords are clear of moving parts.

—Do not exceed the recommended depth of cut, cutting speeds, and feeds.

—Keep areas around machines clear of obstructions and ensure a nonskid surface is available for the equipment operator.

—Remove chips with a brush or other suitable tool; never by hand or with compressed air.

—When operating the brake press, always disconnect the foot switches and ensure that the eccentrics are in the bottom stroke before setting or adjusting the punch and die.

—Place eccentrics on the bottom center of the drop shear bed.

—When operating the brake press, place hands under the plate. Be sure the head and upper body are clear from the plate. Do not lean over the work while bending the plate.

—Magnetic particle test equipment is capable of producing current in excess of 600 amperes. Follow all electrical safety precautions; failure to do so may result in serious injury or death.

—In all machine work, stress **SAFETY** first, **ACCURACY** second, and **SPEED** last. Excessive speed is both dangerous and unproductive.

SAFETY WITH PORTABLE POWER TOOLS

Safety is a very important factor in the use of portable power tools and cannot be overemphasized. The hazards associated with the use of portable power tools are electric shock, cuts, flying particles, explosions, and so on. Because you will be using portable power drills, hammers, and grinders in the shop and out on the job, you should be thoroughly familiar with the operation and care of these tools and with all applicable safety precautions. The portable power tools that you use may be powered by electric motors or by air (pneumatic) motors. Whether electrically powered or air powered, the tools and procedures for using them are basically the same. Safe pratice in the use of these tools will reduce or eliminate the mishap potential. By observing the following safety guidelines, you can ensure maximum benefits from the tools you use and reduce to a minimum the chances of serious injury.

● Never operate any portable power tools unless you are completely familiar with their controls and features.

● Inspect all portable power tools before using them. See that they are clean and in good condition.

● Make sure there is plenty of light in the work area. Never work with power tools in dark areas where you cannot see clearly.

● Before connecting power tools to a power source, be sure the tool switch is in the OFF position.

- When operating a power tool, give it your full and undivided attention.

- Do not distract or in any way disturb another person while they are operating a power tool.

- Never try to clear a jammed power tool until it is disconnected from the power source.

- After using a power tool, turn off the power, disconnect the power source, wait for all movement of the tool to stop, and then remove all waste and scraps from the work area. Store the tool in its proper place.

- Do not allow power cords to come in contact with sharp objects, nor should they kink or come in contact with oil, grease, hot surfaces, or chemicals.

- Never use a damaged cord. Replace it immediately.

- Check electrical cables and cords frequently for overheating. Use only approved extension cords, if needed.

- Always connect the cord of a portable power tool into the extension cord before the extension cord is inserted into a live receptacle.

- Always unplug the extension cord from the receptacle before the cord of the portable power tool is unplugged from the extension cord.

- See that all cables and cords are positioned carefully so they do not become tripping hazards.

- Treat electricity with respect. If water is present in the area of electrical tool operation, be extremely cautious and, if necessary, disconnect the power tool.

- The air pressure for any pneumatic tool must not exceed 90 psi.

- Never point the air hose at another person.

- When working with pneumatic tools, always stand so you are properly balanced while working so you will not slip and lose control of the tool.

CHEMICAL/SOLVENT HAZARDS

Exposure to chemical hazards may cause significant health problems. Solvents are capable of damaging your respiratory system in cases of prolonged inhalation. Chemicals and solvents come in the form of gas, vapor, mist, dust, or fumes. Materials ordinarily thought to be safe may be rendered hazardous under certain use conditions by the uninformed user. As an HT, you will inevitably come into contact with various chemicals/solvents. Most of these chemicals will have some type of hazard associated with them. Among these hazards are irritants, toxics, corrosives, and flammables.

Personnel engaged in the handling and use of chemicals must always use appropriate protective equipment for the class of chemical being used.

Such protective equipment includes, but is not limited to, the following items:

- Rubber gloves, boots, and aprons

- Air masks, respirators, and filter masks

- Eye protection, goggles, and face shields

- Protective skin creams, when sensitive or skin irritants are used

- Any other protective equipment that is necessary

Following is a list of safety precautions that you should observe when using and handling chemicals/solvents:

—Review the Material Safety Data Sheet (MSDS) for any chemical prior to using or handling it.

—Do not work alone in a poorly ventilated space.

—Do not apply solvents to warm or hot equipment, since this increases the potential evaporation rate making it more hazardous.

—Never use a solvent in the presence of any open flame.

—Place a fire extinguisher close by, ready for use.

—Hold the nozzle close to the object being sprayed.

—Personnel who use potential irritants, such as epoxy, resins, and hardeners, should avoid direct skin contact. Should contact be made with an irritant, the area should be washed thoroughly with soap and water. Irritants require no special storage other than that required by their other properties, such as flammability or toxicity.

—All hazardous materials used by the Navy is required to be correctly labeled.

—In compliance with the Occupational Safety and Health Administration (OSHA). a fire resistant hydraulic fluid must be used when filling the reservoir of a hydraulic power rig.

—Dispose of solvent-soaked rags in a container designed for flammable disposal. Wear rubber protective gloves when handling solvents and be sure that ventilation is adequate.

—Do not allow eating, drinking, or smoking in the area where solvents are being used. Any chemicals or solvents should be handled with caution.

—Cutting and grinding of reinforced plastic laminates generate a fine dust that irritates the skin and eyes. Inhalation of the dust should be avoided.

—Keep chemical containers clearly labeled and tightly covered when they are not in use. When mixing a polyester resin, never mix the catalyst and accelerator directly together or an explosion may result. Always mix chemicals according to instructions.

—Many solvents give off toxic vapors and are dangerous upon contact with the skin. Wear respirators and rubber gloves, as appropriate, when handling solvents and ensure that the working area is well ventilated.

—Do not use solvents and degreasers of the halogen family (for example, freon and trichloroethane) near the cutting operation, because light from the arc can break them down into toxic components (phosgene gas).

—If clothing becomes contaminated, remove it and wash it thoroughly before reuse.

—When working in confined spaces, be sure there is adequate ventilation. Where such ventilation cannot be provided, organic respirators are required for protection against vapors.

—Always wash exposed skin areas thoroughly when you are finished working.

WELDING HAZARDS AND PRECAUTIONS

As an HT, one of your main jobs will be welding. You must use extreme care when welding. Safety must always be practiced by people working around or with arc welding equipment. Welding performed with proper safety equipment presents no great safety hazards. You should learn the correct procedures for arc welding in order that the hazards that exist may be properly observed and eliminated, and, if possible, injury avoided.

The chief hazards to be avoided in arc welding are as follows:

● Radiation from the arc, in the form of ultraviolet and infrared rays

● Flying sparks and globules of molten metal

● Electric shock

● Metal fumes

● Burns

Radiation from the arc presents some dangers. Eyes must be protected from radiation from the arc by use of an arc welding helmet or face shield with approved lenses.

Your face, hands, arms, and other skin surfaces must be covered to prevent exposure to the radiation. Gloves should be worn and other parts of the body covered by clothing of sufficient weight to shut out the rays of the arc. Without proper clothing, burns comparable to sunburn will result.

When possible, all arc welding operations should be shielded so that no one may accidentally look directly at the arc or have it shine or reflect into their eyes. An arc "flash" may cause a person to be temporarily blinded, by causing the person to see a white spot similar to a photographer's flash. The severity of an arc flash and the time it will take to recover varies with the length of time a person was exposed to the arc. A long

exposure has been known to cause permanent damage to the retina of the eye. If someone is severely "flashed," special treatment should be administered at once by medical personnel.

Arc welding is usually accompanied by flying sparks, which present a hazard if they strike unprotected skin, lodge on flammable clothing, or hit any other flammable material. When arc welding, you should wear suitable weight clothing and cuffless trousers. Cover your pockets so they will not collect sparks, and remove any flammable materials, such as matches, plastic combs, or gas lighters. You should also ensure that you wear the proper foot protection. High top boots or boondockers with steel toes should be worn.

Hot metal will cause severe bums and should never be handled with bare hands until it has cooled naturally or has been quenched in the quenching tank. Therefore, you should use leather gloves with tight fitting cuffs that fit over the sleeves of the jacket. Many welders wear a full set of leathers that consists of the following:

● Jacket or set of sleeves

● Gauntlet gloves

● Leggings

● Spats

● Apron

● Welders hat liner

Following is a list of other safety precautions that you should keep in mind when performing welding operations:

—The possibility of dangerous electric shock can be avoided by using insulated electrode holders and wearing dry leathers and gloves. When possible, avoid using arc welding equipment in wet or damp areas. ARC WELDING SHOULD NEVER BE DONE IN AN AREA THAT IS NOT WELL VENTILATED.

—Use a welding helmet with a No. 10 or No. 12 shade along with good quality work clothing and gauntlet-type gloves. Wear ear protection when sound-pressure levels exceed 84 dB(A).

—In gas welding, the high temperatures of the welding flame and the sparks created by the welding process will burn skin. Gas welding can also cause radiation burns due to infrared rays emitted by the red hot material. Flame-resistant or flame-retardant clothing must be worn and the hair protected at all times.

—Fluxes used in certain welding and brazing processes produce vapors that are irritating to the eyes, nose, throat, and lungs. Oxides produced by these volatile elements are very poisonous. Therefore, welding must be performed in a well-ventilated area and approved safety goggles must always be worn. The darkest shade of the goggles that still show a clear outline of the work without producing eyestrain are recommended. Sun glasses are not adequate.

—Do not smoke or work near hot surfaces or open flames.

SOLDERING AND BRAZING SAFETY PRACTICES

Soldering or brazing with or on alloys containing cadmium or beryllium can be extremely hazardous. Fumes from cadmium or beryllium compounds are extremely toxic. In fact, several deaths have been reported from inhaling cadmium oxide fumes.

Skin contact with cadmium and beryllium should also be avoided. An expert in industrial hygiene should be consulted whenever cadmium or beryllium compounds are to be used or when repairs are to be made on parts containing the metals.

Fluxes containing fluoride compounds are also toxic. Good ventilation is essential when soldering or brazing and the operator must always observe good safety practices.

A common hazard when soldering is exposure of the skin, eyes, and clothing to acid fluxes. You should observe the following safety precautions when soldering or brazing:

—Always work in a way that flux will not be spilled on the skin or clothing.

—Always wear chemical splashproof goggles, rubber gloves, and long sleeves when using cleaning solutions, pickling solutions, or acids.

—If at any time you are exposed to any chemical solutions, acids, or fluxes, wash the affected area at once, and seek medical attention immediately.

—Remember, heating soldering coppers sometimes presents a fire hazard if an open flame is used. Be sure all flammable material is removed or kept away from the heating flames.

—Make sure there are no flammable vapors present, such as gasoline, acetylene, or other flammable gases, where the hot work is to be performed.

—No job should ever be started until all safety precautions have been taken, and the fire marshal notified, if applicable.

CUTTING HAZARDS AND PRECAUTIONS

Another part of your job will involve cutting operations such as oxyacetylene cutting and plasma arc cutting. Observe the following safety precautions when performing any cutting operation:

—Never place hands or fingers between the metal plate and the bed. Never place hands under the holddowns or knife. Ensure that all personnel are clear from the piece being cut.

—Ensure that the plate is supported so that injuries to personnel can be avoided if the cut end of the metal falls away.

—When using oxyacetylene cutting equipment, ensure that the work area is gas-free. This is particularly important when working in bilges and other spaces where dangerous vapors may collect.

—The high-pressure oxygen stream used in cutting with an oxyacetylene torch can throw molten metal for a distance of 50 to 60 feet. Always post a fire watch to protect the surrounding areas and personnel.

—When using oxyacetylene cutting equipment, ensure that any interfering system has been removed and tagged out, if necessary.

—Install all covers, insulators, and handles before attempting to operate the plasma arc cutting equipment.

—When using plasma arc cutting equipment, open all primary disconnect switches before charging any electrical connections.

FIRST AID

You must always observe safety precautions when working on equipment or operating machinery. Because of the danger of electric shock from equipment and operating machinery, the possibility of receiving burns from welding, and the possibility of a body part being cut when performing cutting operations, it is important that you know and be able to perform the proper action when a mishap occurs. The following paragraphs will briefly describe some of first-aid techniques that you should be familiar with.

RESUSCITATION

Methods of resuscitating or reviving an electrical shock victim include artificial ventilation (to reestablish breathing) and cardiopulmonary resuscitation (to reestablish heartbeat and blood circulation).

Artificial Ventilation

A person who has stopped breathing is not necessarily dead, but is in immediate critical danger. Life depends on oxygen that is breathed into the lungs and then carried by the blood to every body cell. Since body cells cannot store oxygen, and since the blood can hold only a limited amount (and only for a short time), death will surely result from continued lack of breathing.

The heart may continue to beat and the blood may still be circulated to the body cells for some time after breathing has stopped. Since the blood will, for a short time, contain a small supply of oxygen, the body cells will not die immediately. Thus, for a very few minutes, there is some chance that the person's life may be saved. A person who has stopped breathing but who is still alive is said to be in a state of respiratory failure. The first-aid treatment for respiratory failure is called artificial ventilation/respiration.

The purpose of artificial ventilation is to provide a method of air exchange until natural breathing is reestablished. Artificial ventilation should be given only when natural breathing has stopped; it must NOT be given to any person who is still breathing. Do not assume that breathing has stopped merely because a person is unconscious or because a person has been rescued from an electrical shock Remember, DO NOT GIVE ARTIFICIAL VENTILATION TO A PERSON WHO IS BREATHING NATURALLY. There are two

methods of administering artificial ventilation: mouth-to-mouth and mouth-to-nose.

For additional information on performing artificial ventilation, refer to *Standard First Aid Training Course,* NAVEDTRA 10081-D.

Cardiopulmonary Resuscitation

When there is a complete stoppage of heart function, the victim has suffered a cardiac arrest. The signs include the absence of a pulse, because the heart is not beating, and the absence of breathing. In this situation, the immediate administration of cardiopulmonary resuscitation (CPR) by a rescuer using correct procedures greatly increases the chances of a victim's survival.

CPR consists of external heart compression and artificial ventilation. The compressions are performed by pressing the chest with the heel of your hands, and the lungs are ventilated either by mouth-to-mouth or mouth-to-nose techniques. To be effective, CPR must be started within 4 minutes of the onset of cardiac arrest.

CAUTION

CPR should not be attempted by a rescuer who has not been properly trained. Improperly done, CPR can cause serious damage to a victim. Therefore, CPR is **NEVER** practiced on a healthy individual. For training purposes, a training aid is used instead. To learn CPR, you should take an approved course from a qualified CPR instructor.

For additional information on administering CPR, refer to *Standard First Aid Training Course,* NAVEDTRA 10081-D.

WOUNDS

A wound, or breaking of the skin, is another problem that could be the result of an electrical shock. You could accidentally suffer an electrical shock, which could cause a loss of balance. This could result in a minor or serious injury. Because you could be in a critical situation to save someone's life, or even your own, you should know the basics of first aid.

Wounds are classified according to their general condition, size, location, how the skin or tissue is broken, and the agent that caused the wound.

When you consider the manner in which the skin or tissue is broken, there are four general kinds of wounds: abrasions, incisions, lacerations, and punctures.

Abrasions

Abrasions are made when the skin is rubbed or scraped off. Rope bums, floor burns, and skinned knees or elbows are common examples of abrasions. There is usually minimal bleeding or oozing of clear fluid.

Incisions

Incisions, commonly called cuts, are wounds made with a sharp instrument, such as a knife, razor, or broken glass. Incisions tend to bleed very freely because the blood vessels are cut straight across.

Lacerations

Lacerations are wounds that are torn, rather than cut. They have ragged, irregular edges and masses of torn tissue underneath. These wounds are usually made by blunt forces, rather than sharp objects. They are often complicated by crushing of the tissues as well.

Punctures

Punctures are caused by objects that penetrate some distance into the tissues while leaving a relatively small surface opening. As a rule, small punctures do not bleed freely; however, large puncture wounds may cause severe internal bleeding.

A puncture wound can be classified as penetrating or perforating. A perforation differs from a penetration in that it has an exit as well as an entrance site.

For additional information on the treatment of wounds refer to *Standard First Aid Training Course,* NAVEDTRA 10081-D.

BLEEDING

The first-aid methods that are used to stop serious bleeding depend upon the application of pressure. Pressure may be applied in three ways: (1) directly to the wound, (2) at key pressure points throughout the body, and (3) with a tourniquet.
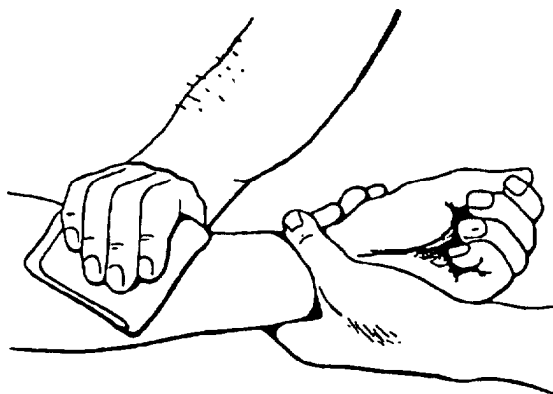
Direct Pressure

You should try the direct-pressure method first to control bleeding. Place a sterile first-aid dressing, when available, directly over the wound. Tie the knot only tight enough to stop the bleeding, and firmly fasten it in position with a bandage. In the absence of sterile dressings, use a compress made with a clean rag, handkerchief, or towel to apply direct pressure to the wound, as in figure 1-2. If the bleeding does not stop, firmly secure another dressing over the first dressing, or apply direct pressure with your hand or fingers over the dressing. Under no circumstances is a dressing to be removed once it is applied.

Pressure Points

If the direct-pressure method does not stop the bleeding, use the pressure point nearest the wound, as shown in figure 1-3. Bleeding from a cut artery or vein may often be controlled by applying pressure to the appropriate pressure point. A pressure point is a place where the main artery to the injured part lies near the skin surface and over a bone. Pressure at such a point is applied with the fingers or with the hand; no first-aid materials are required. Pressure points should be used with caution, as they may cause damage to the limb as a result of an inadequate flow of blood. When the use of pressure points is necessary, do not substitute them for direct pressure; use both.

Use of a Tourniquet

A tourniquet is a constricting band that is used to cut off the supply of blood to an injured limb. It cannot be used to control bleeding from the head, neck, or body, since its use in these locations would result in greater injury or death. A tourniquet should be used on an injured limb only as a last resort for severe, life-threatening hemorrhaging that cannot be controlled by any other method. A tourniquet must be applied ABOVE the wound—that is, towards the trunk—and it must be applied as close to the wound as practicable.

Any long, flat material can be used as a band for a tourniquet—belts, stockings, flat strips of rubber, or a neckerchief. Only tighten the tourniquet enough to stop the flow of blood. Use a marker, skin pencil, crayon, or blood, and mark a large T on the victim's forehead.

WARNING

Remember, a tourniquet is only used as a last resort to control bleeding that cannot be controlled by other means. Tourniquets should be removed as soon as possible by medical personnel only.
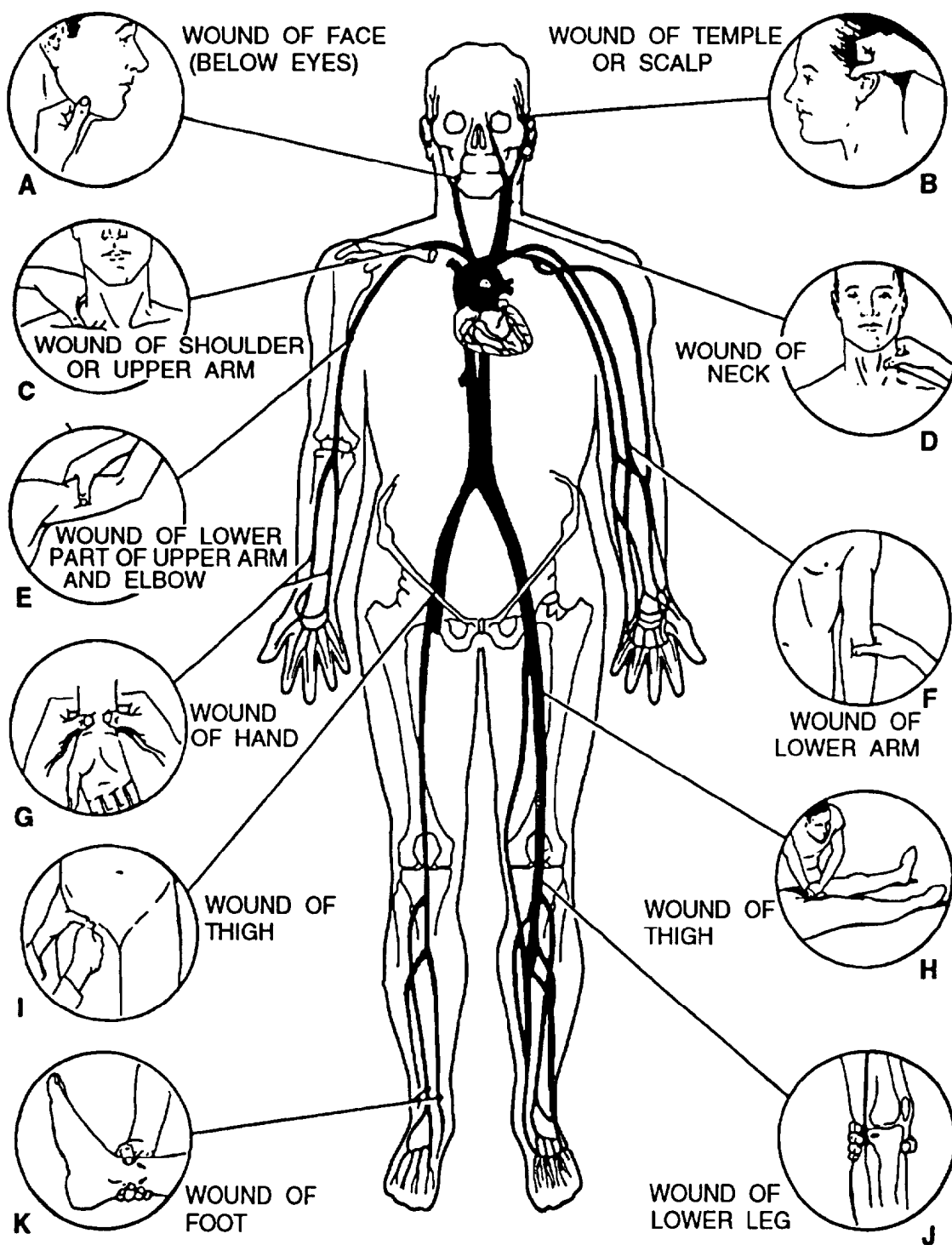

BURNS

The causes of burns are generally classified as thermal, electrical, chemical, or radiation. Whatever the cause, shock always results if the burns are extensive.

Thermal burns are caused by exposure to intense heat, such as that generated by fire, bomb flash, sunlight, hot liquids, hot solids, and hot gases. Their care depends upon the severity of the bum and the percentage of the body area involved.

Electrical burns are caused by electric current passing through tissues or the superficial wound caused by electrical flash. They may be far more serious than they first appear. The entrance wound may be small; but as electricity penetrates the skin, it burns a large area below the surface. Usually there are two external burn areas: one where the current enters the body, and another where it leaves.

Chemical burns for the most part are not caused by heat, but by direct chemical destruction of body tissues. When acids, alkalies, or other chemicals come in contact with the skin or other body membranes, they can cause injuries that are generally referred to as chemical burns. The areas most often affected are the extremities, mouth, and eyes. Alkali burns are usually

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Figure 1-2.—Direct pressure.

Figure 1-3.—Pressure points for control of bleeding.

more serious than acid burns, because they penetrate deeper and burn longer. When chemical burns occur, emergency measures must be carried out immediately. Do not wait for the arrival of medical personnel.

Radiation burns are the result of prolonged exposure to the ultraviolet radiation. First- and second-degree burns may develop. Treatment is essentially the same as that for thermal bums.

Classification of Burns

Burns are classified in several ways: by the extent of the burned surface, by the depth of the burn, and by the cause of the burn. The extent of the body surface burned is the most important factor in determining the seriousness of the burn and plays the greatest role in the victim's chances of survival.
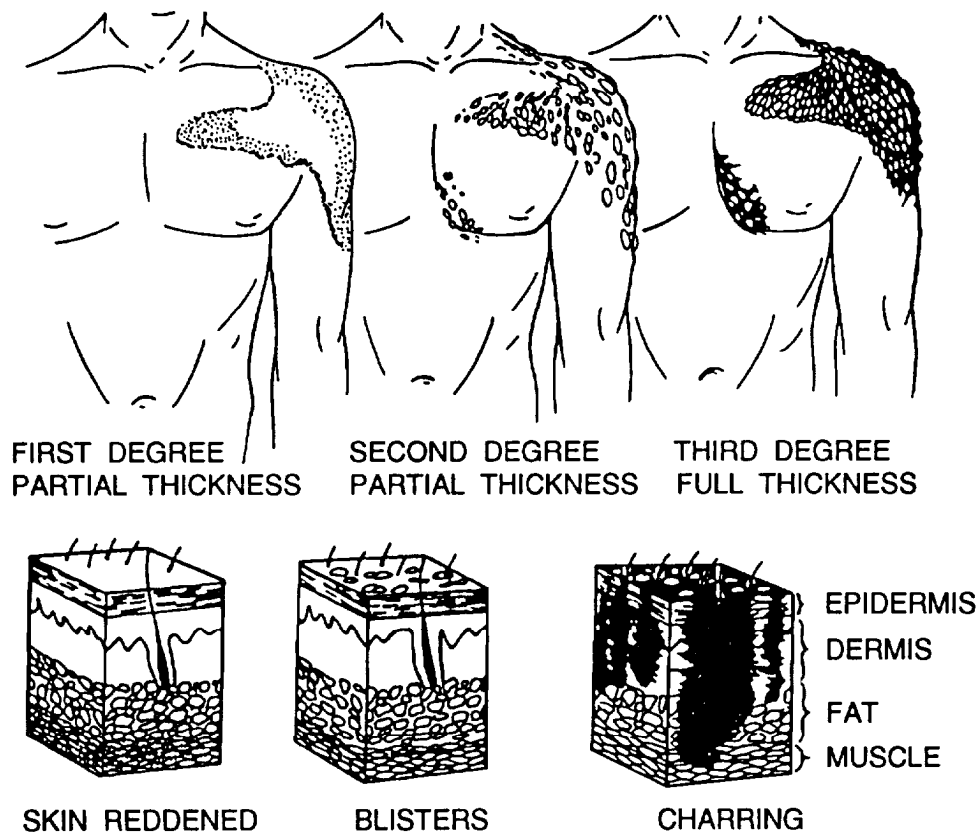
Burns may also be classified as first, second, or third degree, based on the depth of skin damage (fig. 1-4). First-degree burns are mildest. Symptoms are reddening of the skin and mild pain. Second-degree burns are more serious. Symptoms include blistering of the skin, severe pain, some dehydration, and possible shock. Third-degree burns are worst of all. The skin is destroyed and possibly the muscle tissue and bone in severe cases. The skin may be charred or it may be white or lifeless. This is the most serious type of burn, as it produces a deeper state of shock and will cause more permanent damage. It is usually not as painful as a second-degree burn because the sensory nerve endings have been destroyed.

Emergency Treatment of Burns

The degree of the burn, as well as the skin area involved, determines the procedures used in the treatment of burns. Large skin areas require a different approach than small areas. To estimate the amount of skin area affected, the extent of burned surface, the "Rule of Nines" (fig. 1-5) is used. These figures aid in determining the correct treatment for the burned person.
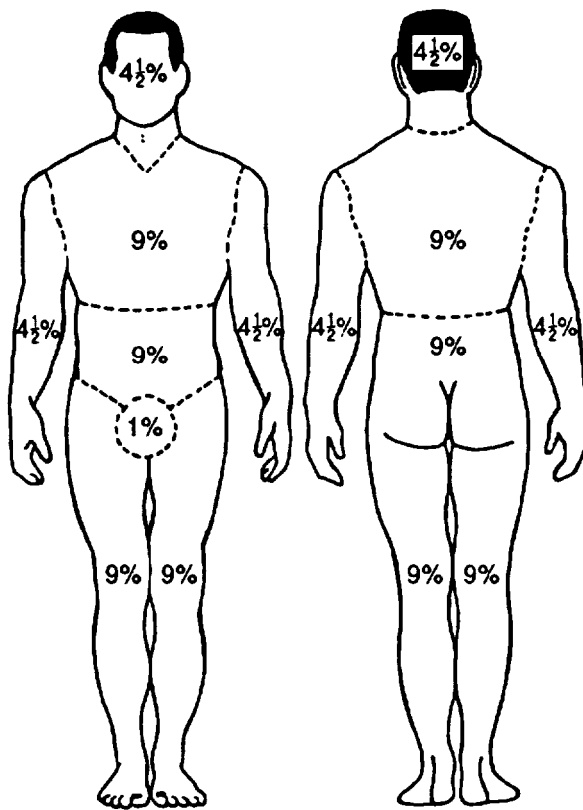
As a guideline, consider that burns exceeding 15 percent of the body surface will cause shock; burns exceeding 20 percent of the body surface endanger life; and bums covering more than 30 percent of the body surface are usually fatal if adequate medical treatment is not received.

Minor burns, such as first-degree burns over less than 20 percent of the body area and small second-degree bums, do not usually require immediate medical attention unless they involve the facial area.

FIRST DEGREE PARTIAL THICKNESS   SECOND DEGREE PARTIAL THICKNESS   THIRD DEGREE FULL THICKNESS

EPIDERMIS
DERMIS
FAT
MUSCLE

SKIN REDDENED   BLISTERS   CHARRING

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Figure 1-4.—First-, second-, and third-degree burns.

Figure 1-5.—Rule of Nines.

THERMAL BURNS.—When emergency treatment of the more serious thermal burns is required, first check the victim for respiratory distress. Burns around the face or exposure to hot gases or smoke may cause the airway to swell shut. If facial burns are present, place the victim in a sitting position to further ease breathing. Transport the victim with facial burns to a medical facility as soon as possible.

Remove all jewelry and similar articles, even from unburned areas, since severe swelling may develop rapidly.

To relieve pain initially, apply cold compresses to the affected area or submerge it in cold water. Cold water not only minimizes pain, but also reduces the burning effects in the deep layers of the skin. Gently pat dry the area with a lint-free cloth or gauze.

Cover the burned area with a sterile dressing, clean sheet, or unused plastic bag. Coverings such as blankets or other materials with a rough texture should not be used because lint may contaminate and further irritate the injured tissue. When hands and feet are burned, dressings must be applied between the fingers and toes to prevent skin surfaces from sticking to each other.

Do not attempt to break blisters, and do not remove shreds of tissue or adhered particles of charred clothing. Never apply greasy substances (butter, lard, or petroleum jelly), antiseptic preparations, or ointments.

If the victim is conscious and not vomiting, prepare a weak solution of salt (1 teaspoon) and baking soda (1/2 teaspoon) in a quart of warm water. Allow the victim to sip the drink slowly. Aspirin is also effective for the relief of pain.

Treat for shock. Maintain the victim's body heat, but do not allow the victim to become overheated. If the victim's hands, feet, or legs are burned, elevate them higher than the heart.

ELECTRICAL BURNS.—In electrical shock cases, burns may have to be ignored temporarily while the patient is being revived. After the patient is revived, lightly cover the burn with a dry, preferably sterile, dressing, treat for shock, and transport the victim to a medical facility.

CHEMICAL BURNS.—To treat most chemical burns, you should begin flushing the area immediately with large amounts of water. Do not apply the water too forcefully. If necessary, remove the victim's clothing, including shoes and socks, while flushing.

Water should not be used for alkali burns caused by dry lime unless large amounts of water are available for rapid and complete flushing. When water and lime are mixed they create a very corrosive substance. Dry lime should be brushed from the skin and clothing.

Isopropyl or rubbing alcohol should be used to treat acid burns caused by phenol (carbolic acid). Phenol is not water soluble; therefore, water should only be used after first washing with alcohol or if alcohol is not available.

For chemical burns of the eye, flush immediately with large amounts of fresh, clean water. Acid bums should be flushed at least 15 minutes, and alkali burns for as long as 20 minutes. If the victim cannot open the eyes, hold the eyelids apart so water can flow across the eyes. After thorough irrigation, loosely cover both eyes with a clean dressing.

The after care for all chemical burns is similar to that for thermal burns. Cover the affected area and get the victim to a medical facility as soon as possible.

RADIATION BURNS.—For first- and second-degree sunburns, treatment is essentially the same as for thermal burns. If the bum is not serious, and the victim does not need medical attention, apply commercially prepared sunburn lotions and ointments.

For further information on the treatment of burns, refer to *Standard First Aid Training Course,* NAVEDTRA 10081-D.

HEARING CONSERVATION AND NOISE ABATEMENT

Historically, hearing loss has been recognized as an occupational hazard related to certain trades, such as blacksmithing and boilermaking. Modern technology has extended the risk to many other activities: using presses, forging hammers, grinders, saws, internal combustion engines, or similar high-speed, high-energy processes. Exposure to high-intensity noise occurs as a result of either impact noise, such as gunfire or rocket fire, or from continuous noise, such as jet or propeller aircraft, marine engines, and machinery.

Hearing loss has been and continues to be a source of concern within the Navy, both ashore and afloat. Hearing loss attributed to such occupational exposure to hazardous noise, the high cost of related compensation claims, and the resulting drop in productivity and efficiency have highlighted a significant problem that requires considerable attention. The goal of the Navy Hearing Conservation Program is to prevent occupational noise-related hearing loss among Navy personnel. The program includes the following elements:

- Work environments will be surveyed to identify potentially hazardous noise levels and personnel at risk.

- Environments that contain, or equipment that produces, potentially hazardous noise should be modified to reduce the noise to acceptable levels whenever technologically and economically feasible. When this is not feasible, administrative control (for example, stay times) and/or hearing protection devices should be used.

- Periodic hearing testing must be conducted to monitor the effectiveness of the program.

- Navy personnel must be educated on the Hearing Conservation Program to ensure the overall success of the program.

IDENTIFYING AND LABELING OF NOISE AREAS AND EQUIPMENT

Hazardous noise areas and equipment must be so designated and appropriately labeled. Areas and equipment that produce continuous and intermittent sound levels greater than 84 dB(A) or impact or impulse levels of 140 db peak are considered hazardous.

An industrial hygienist with a noise level meter will identify the noise hazardous areas. Noise hazardous areas will be labeled using a hazardous noise warning decal, NAVMED 6260/2 (fig. 1-6). This decal will be posted at all accesses. Hazardous noise labels, NAVMED 6260/2A, are the approved labels for marking portable and installed equipment.

All personnel that are required to work in designated noise hazardous areas or with equipment that produces sound levels greater than 84 db(A) or 140 db sound/pressure levels are entered in the hearing conservation program.

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Figure 1-6.—Hazardous noise warning decal.

You will find further information on hearing conservation in OPNAVINST 5100.23C, *Navy Occupational Safety and Health (NAVOSH) Program Manual,* and OPNAVINST 5100.19B, *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat.*

MONITORING HEARING TESTS

All naval personnel receive an initial or reference audiogram shortly after entering the service. Thereafter, a hearing test will be conducted at least annually while you are assigned to a noise hazardous environment. Hearing tests will also be conducted when there are individual complaints of difficulties in understanding conversational speech or a sensation of ringing in the ears. The annual audiograms will be compared to the reference (baseline) to determine if a hearing threshold shift has occurred.

HEARING PROTECTIVE DEVICES

Hearing protective devices should be worn by all personnel when they must enter or work in an area where noise levels are greater than 84 dB(A). A combination of insert earplugs and circumaural muffs, which provides double protection, should be worn in all areas where noise levels exceed 104 db(A). Personnel hearing protective devices should be issued to suit each situation.

HEAT STRESS
CONTROL PROGRAM

Heat stress may occur in many work spaces throughout the Navy. Heat stress is any combination of air temperature, thermal radiation, humidity, airflow, and workload that may stress the human body as it attempts to regulate its temperature. Heat stress becomes excessive when your body's capability to adjust is exceeded. This results in an increase in body core temperature. This condition can readily produce fatigue, severe headaches, nausea, and poor physical and/or mental performance. Prolonged exposure to heat stress could cause heatstroke or heat exhaustion and severe impairment of the body's temperature-regulating ability. Heatstroke can be life-threatening if not immediately and properly treated. Recognizing personnel with heat stress symptoms and getting them prompt medical attention is an all-hands responsibility.

As a petty officer or chief petty officer, your role in the command's Heat Stress Program involves adhering to the command's program and reporting heat stress conditions as they occur.

Primary causes that increase heat stress conditions are as follows:

- Excessive steam and water leaks

- Boiler air casing leaks

- Missing or deteriorated lagging on steam piping, valves, and machinery

- Clogged ventilation systems or an inoperative fan motor

- Operating in hot or humid climates

To determine heat stress conditions, permanently mounted dry-bulb thermometers are installed at key watch and work stations. Their readings should be recorded at least once a watch period. When a reading exceeds 100°F (38°C), a heat stress survey must be ordered to determine the safe stay time for personnel.

A heat stress survey is taken with a wet-bulb globe temperature (WBGT) meter. You should compare these readings to the physiological heat exposure limits (PHEL) chart. After comparing the readings with the PHEL chart, you will be able to determine the safe stay time for personnel.

As a petty officer or chief petty officer, you should have a working knowledge of all aspects of the Heat Stress Program so you can recognize heat stress conditions if they occur and take the proper corrective actions.

Further information and guidance of the Navy Heat Stress Program is contained in OPNAVINST 5100.19B, *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat.*

SUMMARY

In this chapter, we have described your responsibilities regarding general and equipment safety, both as an individual and as a petty officer and chief petty officer.

We have identified various sources of safety information that are available to you, and provided you with general and specific safety precautions to assist you in your day-to-day work as a HT.

We have discussed the danger of electrical shock, how to rescue a victim from electrical shock, and the procedures for giving first aid to the victim. We have also briefly discussed the Navy's Hearing Conservation, Noise Abatement, and Heat Stress programs.

Think safety! Always remain alert to possible danger.

CHAPTER 2

SHIP REPAIR

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

● *Describe the different types of repairs and alterations on naval ships.*

● *Describe the basic organization of the Repair Department at intermediate maintenance activities (IMAs).*

● *Describe the basic duties of personnel assigned to IMAs.*

● *Define the Quality Assurance Program.*

● *Explain the quality assurance organization.*

● *Describe the basic requirements for the Quality Assurance Program and its link to maintenance.*

● *Identify the basic work center organization and the role of the work center supervisor.*

● *Be able to make a basic time line and identify its component parts.*

● *Identify the structural parts of a ship and discuss the purpose of the parts.*

INTRODUCTION

Ship's can operate only a certain length of time without repairs. To keep a ship in prime condition, constant attention should be given to material upkeep and definite intervals of time must be allotted for general overhaul and repair.

Even when regular maintenance procedures are carefully followed, accidents and derangements may necessitate emergency repair work. Defects and deficiencies that can be corrected by ship's force should be dealt with as soon as possible. When repairs are beyond the capacity of ship's force to accomplish, aid must be obtained from a repair activity afloat or ashore.

Ship repair is the basic duty of the HT whether ashore or afloat. The majority of personnel in the HT rate are assigned to billets at IMAs performing the basic functions of ship repair. Therefore, you can expect that sometime in your career you will be assigned to an IMA. It is important that you have a basic idea of the organization and role that an IMA plays in ship's maintenance.

Quality assurance (QA) also impacts every maintenance procedure performed by ship's personnel or maintenance personnel assigned to IMAs. QA has become a prime consideration when performing maintenance on any ship's system. You will use the QA guidelines as established by your command on a daily basis.

This chapter covers basic repair, alteration, and maintenance procedures for naval ships. It also covers the the IMA organization, the QA program, the the basic structural parts of a ship.

REPAIRS AND ALTERATIONS

Corrective maintenance and repairs to ships may be divided into the general categories of (1) repairs, (2) alterations equivalent to repairs, and (3) alterations. It is important that you have an understanding of the different types of repairs and the difference between a repair and an alteration.

REPAIRS

A repair is defined as the work necessary to restore a ship or an article to serviceable condition without a change in design, material, or in the number, location, or relationship of parts. Repairs may be done by ship's force, tenders, ship repair facilities, or by naval or civilian shipyards.

ALTERATIONS EQUIVALENTTO REPAIRS

Before we discuss alterations, we need to understand that NAVSEASYSCOM may determine that some work requested as an alteration may be better defined as an alteration equivalent to repair. In that case, NAVSEASYSCOM forwards the request to the appropriate type commander (TYCOM) to be handled as a repair. An alteration is considered to be an alteration equivalent to a repair if it meets one or more of the following conditions:

- Materials that have previously been approved for similar use and that are available from standard stock are substituted without other change in design.

- Worn out or damaged parts, assemblies, or equipment requiring renewal will be replaced by those of a later and more efficient design that have been previously approved.

- Parts that require repair or replacement to improve reliability of the parts and of the unit will be strengthened, provided no other change in design is involved.

- Equipment that requires no significant changes in design or functioning but is considered essential to prevent recurrence of unsatisfactory conditions will be given minor modifications.

ALTERATIONS

This section deals only with ship alterations (SHIP-ALTs) as opposed to ordnance alterations (ORDALTs). These are alterations to the hull, machinery, equipment, or fittings that include a change in design, materials, number, location, or relationship of the component parts. This is true regardless of whether the SHIPALT is undertaken separately from, incidental to, or in conjunction with repairs. NAVSEASYSCOM, the forces afloat, or CNO may originate requests for SHIPALTs.

NAVSEASYSCOM Responsibilities

One of NAVSEASYSCOM's prime responsibilities for ship maintenance is to administer SHIPALTs under its technical control. NAVSEASYSCOM keeps informed of technical developments in its day-to-day relations with the forces afloat, the naval shipyards, private industry, and research centers. NAVSEASYS-COM may determine that a particular ship or class of ships should be altered to bring them to a more efficient and modem state of readiness. These alterations may be changes to the hull, such as changes to bulkheads that will strengthen bulkheads or changes to deck arrangements that will provide space for installation of machinery; changes to machinery or substitution of newer and more efficient machinery; changes to equipment, such as the replacement of an item with a more efficient type; or changes in design. NAVSEASYSCOM relies on input from the fleet and unit commanders for the need of new SHIPALTs.

Commanding Officer Responsibilities

When the commanding officer of a ship believes a SHIPALT is necessary, he/she sends a request to NAVSEASYSCOM via the administrative chain of command (3-M systems). Copies of the request are sent to all ships of the type within the fleet for comments as to the value of the SHIPALT for other ships of the same type or class.

INSURV Responsibilities

The reports of the Board of Inspection and Survey (INSURV) are another source of recommended SHIPALTs. When the board completes each material inspection of a ship, it furnishes a list of recommended repairs, alterations, and design changes that it feels should be made. NAVSEASYSCOM normally will not act on those recommendations until the commanding officer of the inspected ship requests the changes, and the TYCOM approves.

TY COM Responsibilities

TYCOMs (or other administrative commanders) must endorse all requests for SHIPALTs addressed to NAVSEASYSCOM. Their endorsements must include

recommendations for or against approval, classification, and applicability to other ships of the type. Copies of the basic request and endorsements are forwarded to other concerned TYCOMs with requests to comment on them for the information of NAVSEASYSCOM.

SHIPALTs

SHIPALTs fall into two broad categories: military SHIPALTS and technical SHIPALTs. If there is a question as to whether a proposed SHIPALT is military or technical, NAVSEA will forward the proposal to CNO for determination. You will most often install technical SHIPALTs.

- MILITARY SHIPALT—A military SHIPALT changes the ship's operational and military characteristics and improves the ship's operational capabilities. Only CNO can approve a military SHIPALT. An example of a military SHIPALT would be the installation of a new weapons system.

- TECHNICAL SHIPALT—A technical SHIP-ALT is one that improves the safety of personnel and equipment and/or improves reliability, ease of maintenance, and efficiency of equipment. A technical SHIPALT can only be approved at the NAVSEA level.

AMALGAMATED MILITARY AND TECHNICAL IMPROVEMENT PLAN

Approved military and technical SHIPALTs are ranked in order of priority on an annual basis in the Amalgamated Military and Technical Improvement Plan. The decision to install a SHIPALT is based on the priority of the alteration in the Amalgamated Military and Technical Improvement Plan, funding, ship availability, and whether material is available to complete the SHIPALT. When a decision is reached to install a SHIPALT during a given fiscal year, the alteration is entered into the Fleet Modernization Program (FMP). Approved SHIPALTs are authorized by letters issued not less than 180 days before the ship is scheduled to begin overhaul or other types of repair availabilities.

TYPES OF AVAILABILITIES

An availability is the period of time a ship is assigned to undergo maintenance or repair by a repair activity. Only the authority granting the availability can change the allotted period of time. However, a repair activity may recommend a completion date to the granting authority or request an extension of time to complete work already underway. There are several types of ship availabilities that we will define in the next paragraphs. For example, restricted and technical availabilities differ in whether the ship is or is not ready to carry out its mission.

- A RESTRICTED AVAILABILITY (RA) is used to complete specific items of work in a shipyard or SRF; the ship is NOT available to perform its mission during that time.

- A TECHNICAL AVAILABILITY (TA) is used to complete specific items of work in a shipyard or SRF; the ship IS available to perform its mission during that time.

Other types of availabilities identify the type of work to be done and where it will be done.

- A REGULAR OVERHAUL (ROH) AVAILABILITY is used to complete general repairs and alterations in a naval shipyard or other shore-based repair activity. The schedule for an ROH for a given ship varies between 2 and 5 years according to an established cycle. An overhaul can take as little as 2 months for small ships and as much as 18 months for larger ships. ROH planning begins about 18 months before the scheduled overhaul.

- A VOYAGE REPAIR AVAILABILITY is used for repairs while the ship is underway. These are emergency repairs that are necessary if the ship is to continue on its mission, and they can be done without changing the ship's operating schedule. These repairs will be done by the ship's force if possible, or if necessary, by personnel from an IMA, SIMA, or SRF.

- A REGULAR IMA AVAILABILITY is used for general repairs and authorized alterations that are not emergencies. This work is usually beyond the capability of the ship's force and is normally scheduled in advance.

- An EMERGENCY IMA AVAILABILITY is used to repair specific casualties and generally takes first priority at a fleet IMA.

● A CONCURRENT AVAILABILITY is used for ship-to-shop work by the shore IMA, tender, or repair ship. These availabilities are usually scheduled to take place just before a regular shipyard overhaul or restricted availability.

REPAIR ACTIVITIES

Repair activities are set up to do work the ship's forces cannot handle. Repair activities are IMAs, XMAs, SRFs, and shipyards. The type of work and available funds govern the assignment of repair work to repair activities. The office of the Supervisor of Shipbuilding (SUPSHIP) places and administers contracts for the repair or overhaul of naval ships at private shipyards, and contracts for civilian work to be done in IMAs, SIMAs, and SRFs.

Fleet and type commanders usually call on IMAs or SIMAs to handle repairs and alterations under regular, emergency, and concurrent availabilities. If work is beyond an IMAs or SIMA's capability, other activities ashore, such as an SRF or a shipyard, will do it. In the following paragraphs, we will discuss the work done by the ship's forces and IMAs. In addition, we will examine the organization, duties of personnel, and QA procedures used in an IMA.

SHIP'S FORCE MAINTENANCE AND REPAIRS

Each ship's force should be able to make its own normal repairs. To do that, each ship should have the necessary materials, repair parts, tools, and equipment. The most competent and experienced personnel should supervise these repairs. If ship's personnel are not familiar with the needed repairs and tests, or cannot handle a problem for any reason, the CO should request an IMA or shipyard availability. Personnel who are not familiar with these repairs and tests should take advantage of an IMA or SIMA availability to observe how such work is undertaken. If the ship's force needs technical assistance, they should request it from the local TYCOM's maintenance representatives.

The ship's force should follow a regular schedule of preventive maintenance to be sure that equipment and machinery are always ready for service. This includes cleaning, inspections, operations, and tests to ensure trouble-free operation and to detect faults before they become major problems. Some inspections and tests are quite simple; others require planning so they can be done during upkeep or overhaul periods.

INTERMEDIATE MAINTENANCE ACTIVITIES

A ship's effectiveness depends on its ability to function well; therefore, ship's personnel and IMAs have a dual responsibility to keep it in prime condition. That means that the ship's crew routinely handles normal maintenance and repairs and IMAs handle those repairs that a ship's crew cannot handle.

This section deals mostly with those jobs the ship's crew cannot handle and which are done by repair facilities. We will discuss what happens at an IMA or SIMA. The following is a list of the different types of repair facilities:

● An intermediate maintenance activity (IMA) is a repair ship (AR), destroyer tender (AD), or submarine tender (AS).

● A shore intermediate maintenance activity (SIMA) is based on land and offers services similar to those of an IMA.

● A ship repair facility (SRF) is similar to a naval shipyard but on a smaller scale and is usually based outside the continental United States.

● A shipyard is any full-service naval shipyard or a civilian shipyard contracted for Navy work.

While each type of IMA has its special purpose, all of them have many characteristics and facilities in common that make them suitable for general repair work on most ships. Repair ships and tenders perform battle and operational damage repairs on ships in the forward areas, and they provide logistic support to ships of the fleet. They also can provide other services, including medical and dental treatment, for the ships they tend. Their shops can handle hull, machinery, electrical, and ordnance work, and they stock parts to help them deal with most of the repairs they perform.

SIMAs are shore-based facilities that only do repair work, while other departments on a shore base handle the supply, medical, and administrative needs of the ship. Ships are assigned to IMAs with a flexible approach that considers unusual repair requirements and operational commitments, particularly for ships outside the continental United States.

IMA Availabilities

Ships are scheduled for regular IMA availabilities or upkeep periods at certain intervals of time that vary with different types of ships. There are numerous types of availabilities used by TYCOMs and they vary between the surface and submarine components. Therefore, you should always refer to the governing document associated with the command at which you are stationed. The availability periods are usually planned in advance and depend upon the quarterly deployment schedule of each ship.

A ship's commanding officer sends a request for an IMA availability with a forwarding letter to the TYCOM or his or her representative. The request must include job sequence numbers (JSNs) for work requests in the Current Ship's Maintenance Project (CSMP) and a listing of TYCOM master job catalogue work items.

A reviewing officer with TYCOM will review the request and make any necessary corrections to conform to established policies and procedures. Most of the ship's work list items will be approved, but the ship may have to furnish more detailed information on certain work requests.

The reviewing officer will forward the approved ship's work requests to the appropriate IMA well in advance of the period of availability so the IMA repair department personnel can prepare for the work. Because you should know something about these personnel before you learn about the arrival conference, the shops, and the ship maintenance procedures, we will discuss them in the following paragraphs.

Repair Personnel

Standard Organization and Regulations of the U.S. Navy, OPNAVINST 3120.32, contains general information about the relative positions and responsibilities of IMA departments. These positions may vary between the submarine and surface components, but their responsibilities are generally the same. Also, TYCOMs issue standard ship organizations for their type that describe the organization for every routine function and most emergency conditions that can exist aboard ship. The following paragraphs explain the roles of the repair officer, the assistant repair officer, quality assurance officer, planning and estimating officer, repair division officers, diving and salvage officer, and enlisted personnel.

COMMANDING OFFICER.—The IMA's commanding officer has the overall responsibility for the daily operation and function of the IMA as a whole. The CO coordinates the activities of the IMA's departments and divisions and is responsible to the TYCOM.

REPAIR OFFICER.—The repair officer is head of the repair department on an IMA. The repair officer oversees the upkeep, operation, and maintenance of the equipment assigned to the repair department, and the training, direction, and coordination of its personnel. The repair officer keeps up with production and ensures efficient and economical operation of the production process.

ASSISTANT REPAIR OFFICER.—The assistant repair officer assumes the repair officer's responsibilities in his/her absence and carries out the responsibilities the repair officer delegates. This officer usually handles the internal administration of the department and specifically keeps progress records on all work. In the submarine force, the assistant repair officer is called the production management assistant (PMA).

QUALITY ASSURANCE OFFICER.—The quality assurance officer (QAO) is responsible to the commanding officer for planning, monitoring, and executing the overall IMA QA program. The QAO ensures that all work done by the IMA meets all established technical and quality control requirements.

PLANNING AND ESTIMATING OFFICER.—The planning and estimating (P & E) officer is responsible to the assistant repair officer for planning and estimating all work assigned to the IMA. The P & E officer also is tasked with providing technical information for repairs, preparing detailed work packages for controlled work, and maintaining specifications, standards, process instructions, and procedures.

DIVISION OFFICERS.—The division officers (DOs) have both administrative and production responsibilities for the actual work that is done in shops under their supervision. They have administrative and production responsibility. Their administrative responsibility is in the administration of personnel in their respective divisions, including the assignment of berths and watches, and all training and training records. Their production responsibilities include oversight of all work requests and review of progress, requisitions for material, proper operation of division

shops for which they are responsible, safety, and progress reports to the repair officer.

DIVING AND SALVAGE OFFICER.—The position of diving and salvage officer may be a separate assignment or a collateral duty for an officer in the repair department. In either case, the diving and salvage officer is responsible for the supervision of all diving operations, the maintenance of diving and salvage equipment, and compliance with diving instructions and precautions.

ENLISTED PERSONNEL.—Navy enlisted personnel provide the technical skills required aboard IMAs. The *Manual of Navy Enlisted Manpower and Personnel Classifcations and Occupational Standards,* NAVPERS 18068, contains detailed information on the enlisted rating structure.

Arrival Conference

An arrival conference is usually held immediately when a ship begins an IMA availability or an upkeep period. Representatives of the ship, the repair department, and the TYCOM usually attend the conference. They discuss the relative needs of the ship and the urgency of each job and approve/disapprove work requests, clarify uncertainties, and arrange for temporary services such as electricity and steam.

Work Requests

This section will briefly discuss the routing of the work request from the time the ship submits the ship's maintenance request action form (OPNAVINST 4790/2K) until you receive it to begin work.

As mentioned earlier, the ship will submit a 4790/2K to the TYCOM requesting specific maintenance work to be accomplished. The 2K is screened at the TYCOM level for completeness and to determine what type of repair facility to assign the maintenance action to. If the IMA is assigned the maintenance action, the 2K is routed to the Maintenance Document Control Office (MDCO) and the automated data processing (ADP) facility for processing. MDCO and ADP will process the 2K, entering it onto the CSMP and will issue an automated work request (AWR) (fig. 2-1) to the IMA.

When the AWR arrives at the IMA, it is screened by the RO for applicability, shop capability, urgency, and manning requirements. At this point, the AWR may be accepted or rejected by the IMA or deferred to a future IMA availability, depending on shop loading and material availability. Before the AWR is accepted, rejected, or deferred, it will be ship checked by the lead and assist work centers for applicability. If the AWR is accepted for work in the current availability, it will be checked by the P & E and QA divisions for technical and QA requirements and then issued to the shop. Remember, this is a general overview of the work request routing from the customer to the craftsman, and each IMA has different routing sequences as established by TYCOM.

Ship/IMA Work Coordination

Ship's engineering personnel must know the status of work underway during an IMA availability whether that work is being done by the ship's force or the IMA. You need this information to coordinate your own work with that being done by the ship's force. There are three basic kinds of work that require coordination: (1) equipment removed by the ship's force to be delivered to the IMA for repair, (2) equipment dismantled by the ship's crew so they can send parts to the IMA for repair (also known as ship-to-shop jobs), and (3) repairs the IMA force makes on the ship.

The IMA usually appoints a ship superintendent, normally a chief petty officer, who should always know the status of all jobs on the ship and on the IMA. The ship will also normally appoint a chief petty officer for that purpose to interface with the IMA. The person(s) in these positions are a liaison between the ship and the IMA for all work in progress and completed, and all tests required and completed. They should keep a daily running progress report of each job and should report that information daily to the ship's/IMA representative.

Repair Department

You need a general idea of the shops composing the repair department and their functions whether you are assigned to an IMA or are part of a ship's company. In this section, we will describe the shops as they are organized in the divisions on a destroyer tender (AD), which is representative of all surface IMAs. Submarine-related IMAs are organized differently but have the same capabilities.

HULL REPAIR DIVISION (R-1).—The hull repair division consists of the shipfitter shop, sheet metal shop, pipe and copper shop, weld shop, carpenter shop, diving locker, and canvas shop. As an HT, you

AWR
OPNAV 4790/2R (11-73) S/N 0107-LF-770-3005

AUTOMATED WORK REQUEST

COMP

SECTION I. IDENTIFICATION

JOB CONTROL NUMBER

1 SHIP'S UIC	2 WORK CENTER	3 JOB NUMBER	4 APL/AEL
04669	EB01	0111	67382013400

A SHIP'S NAME	6. EQUIPMENT NOUN NAME	13 IDENT/EQUIP SERIAL NO
USS JOHN KING	REEFER COMPRESS	

B HULL NUMBER	14 EIC	16 LOCATION COMPARTMENT	DECK	FRAME	SIDE	15 SAFETY HAZARD
DDG-3	T409	REEFER DECK	3	42	2	

18 CONFIGURATION CHANGES (SHIPALTS, ORDALTS, Field Changes, etc.)

FOR INSURV. BOARD USE

19 '/'	20 INSURV NUMBER	21 SUFFIX	22 U	23 S	24 P/F

SECTION II. DEFERRAL ACTION

26 DEFER DATE	27 S/F MHRS REMAINING	28 DEADLINE DATE	9 OFFER REASON	
6 1 0 5	A U T 0		2	LACK OF MATERIAL

SECTION III. COMPLETED ACTION

29 ACT TKN	30 S/F MHRS	31 COMPLETION DATE		FOR FOR SELECTED EQUIPMENT ONLY		
		YR	DAY	32 ACTIVE MAINT TIME	33 TRBL ISO	34 METER READING

SECTION IV. REMARKS/DESCRIPTION

36 REMARKS/DESCRIPTION

REEFER COMPRESSOR HAS EXCESSIVE NOISE AND VIBRATION REPAIR
OR REPLACE COMPRESSOR

CONT

37 CSMP SUMMARY	COMPRESSOR NOISE FIX/REPLACE	46 SPECIAL PURPOSE	A	B	C	D	E	F	G	H	I	J	K	L

38 FIRST CONTACT/MAINTENANCE MAN	39 SECOND CONTACT/SUPERVISOR	41 PRI	42 T/A	43 INTEGRATED PRIORITY
RYDER MM2	J. COOK ENC	2	2	

E COMMANDING OFFICER'S SIGNATURE	F TYCOM AUTHORIZATION	44 IJC SCREENING	45 TYCOM SCREENING
		2 IMA ACCOM	2 IMA ACCOM

SECTION V. SUPPLEMENTARY INFORMATION

47 S/F BLUEPRINTS TECH MANUAL ETC	335-0665	X	N		ON BRD Y N		Y N		ON BRD Y N

48 REPAIR ACTIVITY BLUEPRINTS PLANS TECH MANUALS, ETC

49 PRE-ARRIVAL/ARRIVAL CONFERENCE ACTION
TYCOM-LIMIT REPAIRS TO 600 M/H AND ROV MATERIAL

50 REMARKS
REP OFF-LIMIT TO 400 M/H

SECTION VI. PLANNING

51 PERIODIC MAINT REQMNT		52 PER	53 YY/MM ISSUED	54 SPECIAL DATA	

55 QUALITY ASSURANCE REQMNTS	a SUBSAFE	c NUCLEAR LEVEL 1	e NUCLEAR WORK PROCEDURES	g SPECIAL CLEANING	i SPECIAL IDENTIFICATION	k RADIOLOGICAL CONTROLS
	b LEVEL 1	d NON-DESTRUCT TEST	f SUBMARINE ANTENNA ENGINEERING DIV	h SPECIAL TESTING	j NOISE CRITICAL	l OTHER CONTROLS

56 SPEC REQMNTS	a KEY EVENT	b SPECIAL INTEREST	c DRY DOCK REQUIRED	d PRE-OVERHAUL TEST REQUIRED	e POST-OVERHAUL TEST REQUIRED	f DEPARTURE REQUIRED

SECTION VII. REPAIR ACTIVITY PLANNING/SCHEDULING ACTION

57 LEAD WC	58 SCHED START	59 SCHED COMP	60 EST MHRS	61 K/O	62 TASK	63 ASST WC	64 SCHED START	65 SCHED COMP	66 EST MHRS	67 K/O	68 TASK
56B	6151	6175	0160	03	OVHL COMP						
69 ASST WC	70 SCHED START	71 SCHED COMP	72 EST MHRS	73 K/O	74 TASK	75 ASST WC	76 SCHED START	77 SCHED COMP	78 EST MHRS	79 K/O	80 TASK
51B	6151	6174	0005	01	DISCON-RECON						
81 ASST WC	82 SCHED START	83 SCHED COMP	84 EST MHRS	85 K/O	86 TASK	87 ASST WC	88 SCHED START	89 SCHED COMP	90 EST MHRS	91 K/O	92 TASK
72A	6151	6173	0020	02	DEL-RETURN						

93 REPAIR ACT UIC	94 WORK REQ ROUTINE NO	95 EST MANDAYS	96 EST MANDAY COST $	97 EST MATERIAL COST $
	5 1 4 2 1			

94 EST TOTAL COST $	99 JOB ORDER NUMBER	100 LEAD P & E CODE	101 DATE OF ESTIMATE

102 FINAL ACTION	103 MHRS EXPENDED	104 DATE COMPLETED	G COMPLETED BY (Signature & Rank)	H ACCEPTED BY (Signature & Rate/Rank)

86NVM008

Figure 2-1.—Automated Work Request.

2-7

will probably be assigned to at least a tour of duty as a member of R-l division. We will explain the duties of personnel assigned to each of these shops in the following paragraphs. On submarine tenders, the carpenter shop, dive locker, and canvas shops are assigned to R-6 division.

Shipfitter Shop.—Personnel make repairs on the hull, manufacture and install various structural metal components, repair or replace watertight fixtures, and handle alterations designated for forces afloat.

Sheet Metal Shop.—Personnel make all types of repairs and fabrications on light gauge sheet metal and handle alterations designated for forces afloat.

Pipe and Copper Shop.—Personnel fabricate and repair most pipe and tubing, test completed work hydrostatically, and handle alterations designated for forces afloat.

Weld Shop.—Personnel weld most metals, including high-pressure welding on boilers. They repair castings, stress relieve castings and forgings, forge special tools and hull fittings, and case harden low-carbon steel.

NOTE: The nondestructive testing laboratory performs all nondestructive testing used to test the quality of the welds and is part of the quality control division, R-8.

Carpenter Shop.—Personnel repair and fabricate most items made of wood, and lay linoleum tile, magnetite, and terrazzo covers on decks. The pattern shop functions under the carpenter shop and fabricates patterns of wood, metal, and plastic for templates and foundry castings.

Canvas Shop.—Personnel fabricate miscellaneous canvas covers, awnings, and boat cloths, and they repair furniture using leather and cloth fabrics.

Diving Locker.—Personnel inspect the underwater portion of the hull and prepare the underwater hull reports for the repair officer. They also replace propellers on destroyers and small ships and repair or replace other items underwater as needed. They clean propellers, sonar domes, sea chests, and large injection valves; clear fouled propellers and sea chests; and maintain the diving boat and diving equipment in repair and operational readiness.

MACHINERY REPAIR DIVISION (R-2).—The machinery repair division consists of the inside machine shop, the outside machine shop, the boiler shop, and the foundry shop. We will explain the duties of personnel assigned to each of these shops in the following paragraphs.

Inside Machine Shop.—Personnel repair or fabricate mechanical parts that require work done on machine shop tools and equipment. They do metal plating and engraving, and they test metals to determine their characteristics. They also handle alterations designated for forces afloat.

Outside Machine Shop.—Personnel shop test and repair all types of machinery used in naval ships. They also handle alterations designated for forces afloat. On submarine tenders, they are assigned to R-9 division.

Boiler Shop.—Personnel shop test, inspect, and repair boilers of naval ships.

Foundry Shop.—Personnel pour castings of various metals to produce repair parts and whole items used on the ship. On submarine tenders, they are assigned to R-6 division.

ELECTRICAL REPAIR DIVISION (R-3).—The electrical repair division consists of the electric shop, the gyro shop, the printing shop, and the photo shop.

Electric Shop.—Personnel inspect, test, repair, and make adjustments to nearly all electrical equipment, and they also handle electrical alterations designated for forces afloat. (On submarine tenders, the print and photo shops are assigned to R-O division.)

ELECTRONICS REPAIR DIVISION (R-4).—The electronics repair division consists of the electronics shop and the calibration shop.

Electronics Shop.—Personnel align and repair all types of electronic equipment, make field changes, and maintain an electronics publications library.

Calibration Shop.—Personnel repair and calibrate most test equipment used on naval ships.

QUALITY ASSURANCE PROGRAM

As an HT, most repairs that you will make require a great deal of quality controls to ensure that the system

you are working on is restored to its original conditions. The QA program provides a uniform policy of maintenance and repair on ships and submarines. It improves discipline in the repair of equipment, safety of personnel, and configuration control. It is essentially a program to ensure that all work meets specifications or that any departure from specifications is approved and documented. You, the supervisor or craftsman, are expected to carry out the QA program. This section will give you the broad knowledge you need to understand how it works.

CONCEPTS OF QUALITY ASSURANCE

The ever-increasing technical complexity of present-day surface ships and submarines has pointed to a need for special administrative and technical procedures known collectively as the QA program. The fundamental QA concept is that all maintenance personnel have the responsibility to prevent defects from the beginning to the end of each maintenance operation. You must consider QA requirements whenever you plan maintenance, and you must apply the fundamental rule—MEET TECHNICAL SPECIFICATIONS AT ALL TIMES.

Quality control (QC) means you regulate events rather than being regulated by them. It means that you work with proper methods, material, and tools. In other words, knowledge is the key, and knowledge comes from factual information.

The QA program provides a way to document and maintain information on the key characteristics of equipment. It helps you base decisions on facts rather than intuition or memory. It provides comparative data that will be useful long after you have forgotten the details of a particular time or event. You can get knowledge from data, ship's drawings, technical manuals, material references (such as APLs), and many other sources. As you use these sources, you will develop the special skills you need to analyze information and supervise QA programs.

A good QA program provides enough information so you can accomplish the following goals:

● Improve the quality, uniformity, and reliability of the total maintenance effort.

● Improve the work environment, tools, and equipment used in maintenance.

● Eliminate unnecessary man-hour and dollar expenses.

● Improve the training, work habits, and procedures of maintenance personnel.

● Store, locate, and distribute required technical information more effectively.

● Plan realistic material and equipment/ maintenance tasks.

THE QA MANUALS

The Navy's fleet commanders in chief (CINCs) publish and update QA manuals that set forth minimum QA requirements for both the surface fleets and the submarine force. The TYCOMs then publish QA manuals that apply to their forces but are based on the fleet CINC manuals. Since these CINC and TYCOM manuals apply to a wide range of ship types, equipment, and resources, the instructions are general in nature. Therefore, each activity must implement its own QA program that meets the intent of the latest versions of the fleet CINC and TYCOM QA manuals. If higher authority imposes more stringent requirements, they will take precedence.

The Navy's QA program applies to maintenance done aboard ship by the ship's force, in IMAs, SIMAs, SRFs, and shipyards. However, this section will concentrate on QA work done by the ship's force and IMAs since you may be assigned to either type of duty.

QA PROGRAM COMPONENTS

The basic thrust of the QA program is to ensure that you comply with technical specifications during all work on ships of both the surface fleet and the submarine force. The key elements of the QA program include administrative and job execution components. The administrative component includes the requirement to train and qualify personnel, monitor and audit programs, and complete the QA forms and records. The job execution component includes the requirement to prepare work procedures, meet controlled material requirements, requisition and receive material, conduct in-process control of fabrication and repairs, test and recertify equipment, and document any departure from specifications.

THE QA LINK TO MAINTENANCE

The Navy has a long-standing requirement that maintenance work must meet technical specifications. The person performing the maintenance is ultimately responsible for ensuring that this requirement is met. Therefore, any worker who is expected to do the job properly must be properly trained, provided with correct tools and parts, familiar with the technical manuals and plans, and adequately supervised.

These elements continue to be the primary means of assuring that maintenance is performed correctly.

Once there is a decision to proceed with maintenance, you must apply QA requirements at the same time you plan the maintenance and supervise its completion. Technical specifications will come from a variety of sources. The determination of which sources are applicable to the particular job will be the most difficult part of your planning effort. Once you decide, the maintenance objective becomes two-fold: (1) ensure the maintenance work meets all specifications, and (2) ensure the documentation is complete and accurate and can be audited.

THE QA ORGANIZATION

The Navy's QA program organization begins with the fleet CINCs, who provide the basic QA program organization responsibilities and guidelines. The TYCOMs provide instruction, policy, and overall direction to implement and operate the force QA program. Each TYCOM has a force QA officer assigned to administer the force QA program. Commanding officers are responsible to the TYCOM, via the chain of command, for QA of their organization. The CO is responsible for organizing and implementing a QA program within the organization to carry out the provisions of the TYCOM's QA manual, and assigns key QA personnel for that purpose. In most cases, it is a collateral duty assignment for these key personnel on ships and a primary duty for key personnel at IMAs. The following paragraphs will give you a brief description of the responsibilities of each of these positions followed by a discussion of their training and qualifications.

The Commanding Officer

The CO is responsible for the quality of material within a command, and he/she depends on the full cooperation of all hands to help meet this responsibility.

The CO cannot maintain high standards of quality workmanship by merely creating a QA organization within a maintenance organization. The organization must have the full support of everyone within it. It is not the inspection instruments and instructions that bring high standards of quality; it is the attitudes of those who do the work.

The Quality Assurance Officer

The QAO is responsible to the CO for the organization, administration, and execution of the ship's QA program according to the QA manual. On most surface ships other than IMAs, the QAO is the chief engineer with a senior chief petty officer assigned as the QA coordinator. The QAO is responsible for the following:

— Coordinating the QA training program as an integral part of the ship's/IMA's overall training program

— Maintaining the ship's/IMAs QA records and test and inspection reports

— Maintaining departure-from-specifications records that can be audited

— Reviewing procedures and controlled work packages prepared by the ship/IMA

— Conducting QA audits as required and following up on corrective action to ensure compliance with the QA program

— Preparing QA/QC reports as required by higher authority

— Qualifying key personnel in the QA program.

The Division Officer

The DOs ensure that all division personnel receive the necessary QA training and qualifications for their positions and that they carry out their QA responsibilities.

The Quality Assurance Coordinator

The quality assurance coordinators (QACs) are senior petty officers assigned to this duty. Personnel assigned to this duty train other QA personnel, conduct

interviews for prospective QA personnel, and administer written examinations for QA qualifications.

Ship Quality Control Inspector

If you are a work center supervisor, you will most often be appointed and trained in the collateral duty of ship quality control inspector (SQCI). IMAs have personnel permanently assigned to these positions within the QA division. As an SQCI, you will be deeply and directly involved in QA. You must be familiar with all aspects of the QA program and the QC procedures and requirements of your specialty. As an SQCI, you should act as an inspector or assign a collateral duty inspector at the same time you assign work to be sure the work is inspected in progress and on completion. Do not allow personnel in your shop to do a final inspection on their own work.

Inspections normally fall into one of the following three inspection areas:

● RECEIVING OR SCREENING INSPEC-TIONS. These inspections apply to material, components, parts, equipment, logs and records, and documents. They determine the condition of material, proper identification, maintenance requirements, disposition, and correctness of related records and documents.

● IN-PROCESS INSPECTIONS. These inspections are specific QA actions that are required in cases where you cannot know whether the job was done right without the inspections. They include witnessing, application of torque, functional testing, adjusting, assembling, servicing, and installation.

● FINAL INSPECTIONS. These inspections comprise specific QA actions performed following the completion of a task or a series of tasks. An example is an inspection of work areas after several personnel have completed tasks.

Most commands that have a QA program will issue you a special ID number that will identify you as a qualified SQCI. In addition, the QAO will assign a personal serial number to each shop SQCI as proof of certification to use on all forms and tags that require initials as proof that certified tests and inspections were made. This will provide documented proof and traceability to show that each item or lot of items meets

the material and workmanship for that stage of workmanship.

Personnel who serve as SQCIs will be responsible for the following:

● Developing a thorough understanding of the QA program.

● Training all work center personnel until they are familiar with the QA/QC requirements that apply to your work.

● Ensuring that all controlled work done by your work center personnel meets the minimum requirements in the latest plans, directives, and specifications of higher authority and that controlled work packages (CWPs) are properly used on repair work.

● Inspecting all controlled work for conformance to specifications and witnessing and documenting all tests required on these systems.

● Maintaining records and files to support the QA program and ensuring the QA manual is followed.

● Ensuring test personnel use measuring devices, instruments, inspection tools, gauges, or fixtures that have current calibration stickers or records when acceptance tests are performed.

● Ensuring a qualified inspector accepts the work before the ship installs the product when an inspection is beyond the capability of the ship's/IMA's QA inspector.

● Reporting all deficiencies to the ship's QAC and keeping the division officer informed.

● Helping the DO and QAO conduct internal audits and correct discrepancies.

**Work Center Controlled
Material Petty Officer**

If you supervise a work center that has level I or subsafe material, you must ensure the procedures that govern controlled material are followed. Your work center or division will usually appoint a controlled material petty officer (CMPO) to handle these responsibilities. After training, that person will inspect,

segregate, stow, and issue controlled material in the work center.

Shop Craftsmen

Shop craftsmen are not normally trained in specific QA functions as are the key QA people. Still, they must do their work under QA guidelines if they apply. They will work closely with their shop supervisors and QA inspectors to ensure the work is done according to QA guidelines and procedures.

THE CONTROLLED WORK PACKAGE

As an HT, you will be required to document the repair work that you do on any ship's system. This documentation is done in an approved and issued CWP received from the P & E division. The CWP provides QC requirements and procedures to help ensure that fabrication or repair will produce a quality product. These requirements or procedures include both TYCOM and local command-generated information for work package processing and sign-off. The typical CWP will have QA forms, production task control forms, departure from specifications forms, material deficiency forms, QC personnel sign-off requirements, and hydro or test forms. Each CWP covers the entire scope of the work process and is a permanent and legal record of the performed work. The job control number (JCN) provides traceability from the work package to other certification documentation. When filled in, the CWP documents adherence to specified quality standards.

You must ensure that the CWP is at the job site during the performance of the task. Since the CWP is the controlling documentation for the performance of any repair work you accomplish, it is required on the work site to ensure that no steps or inspection are omitted. If the work procedure requires the simultaneous performance of procedure steps and these steps are done in different locations, use locally developed practices to ensure you maintain control for each step.

Immediately after a job is completed, each assigned work center and the QAO will review the CWP documentation to be sure it is complete and correct. If you and your workers have been doing the assigned steps as stated, this should not be a problem. Be sure all verification signature blocks are signed. Make sure all references, such as technical manuals or drawings, are returned to the appropriate place.

REPAIR PROCEDURES

As an HT, you may be required to organize and supervise an HT shop aboard ship or at a shore facility. It will be your responsibility to supervise and instruct personnel of lower rates in the techniques of carpentry and woodworking, plate and sheet metal layout and fabrication, pipefitting, and the welding of various types of metals. In addition, you will be required to estimate the time, materials, and personnel required for the completion of various wood and metalworking jobs; to maintain the HT shop, including all tools and equipment, in the best possible condition; and to ensure that all safety precautions are observed by your personnel. To supervise HT shop work efficiently, afloat or ashore, you will rely mostly upon your past experience in shop work and repair procedures.

The purpose of this section is to acquaint an HT with some of the most important things that must be considered by a person in charge of a work center. It is impossible, however, to cover all the procedures and problems that arise in the daily operations of a work center. By studying this section of the chapter, you will become aware of some of the things that occur, particularly in regard to the job of setting up shop procedures and the methods by which everyday problems are solved.

Leading petty officers, especially those who are in direct contact with personnel, often fail to recognize that they are part of the ship's administrative organization. Every petty officer in the shipboard organization is definitely part of the administrative group. In such a capacity, you have many responsibilities that you are expected to carry out by interpreting and executing the established policies and procedures. Supervisors can accomplish this properly only when they have a clear understanding of these policies and procedures, as well as their place within the command's organization.

As a supervisor, the petty officer is expected to spot operating difficulties in their shop and do something about them. You must have an understanding of your department, ship's organization, and the proper channels and lines of authority which are open to you. The further up the organizational chain that you progress, the greater your responsibilities become. The job of a supervisor is a detailed one, and most important with respect to the operation of any naval repair activity or facility. A weakness in the performance of any supervisory duty or responsibility reduces the effectiveness of the work center as a whole.

Obviously, then, the HT in charge of an HT shop should fully appreciate and understand the responsibility he/she holds as a member of a shipboard organization, and be able to identify each of his/her duties with respect to any assigned job. This is not an easy task in a field so complex and variable as the work of a shop supervisor.

Some administrative personnel have made long lists of the responsibilities of shop supervisors. A close examination of such lists might disclose to each leading petty officer points of differences as well as points of agreement. Many differences are of minor importance, and others represent major differences in responsibilities. After such a comparison, it might be concluded that an accurate list of duties for any given job can be made only by the individual occupying the particular job. The following list includes the duties and responsibilities that are common to most shop supervisors:

● Getting the right person on the right job at the right time

● Using tools and materials as economically as possible

● Preventing conditions that might cause accidents

● Keeping personnel satisfied and happy on the job

● Adjusting individual grievances

● Maintaining discipline

● Keeping records and making reports

● Maintaining the quality and quantity of repair work

● Planning and scheduling repair work

● Training personnel

● Requisitioning tools, equipment, and materials

● Inspecting and maintaining tools and equipment

● Giving orders and directions

● Cooperating with others

● Checking and inspecting completed repairs or replacement parts

● Promoting teamwork

From the extent of the preceding list it is obvious that the job of a supervisor covers a broad field. These items are quite general in nature; therefore, it is necessary for each HT shop supervisor to carry out a detailed study of his/her own specific duties and responsibilities.

The leading petty officer in charge of an HT shop should take advantage of every opportunity to provide personnel with specific information about their jobs. The type of petty officer who says, "Never mind why; just do as you are told," is rapidly being replaced by the supervisor who recognizes the importance of each individual.

As the leading petty officer in charge of an HT shop, you should use all possible interest factors. You should study each of your personnel and use those interest factors that seem to obtain the best results according to individual characteristics. Your ability to interest your personnel in their work is important, as it determines your success or failure as a supervisor. Your proficiency in rating depends in part on the quality and quantity of work assigned personnel produce, which, in turn, reflects the morale of the shop personnel and their interest in their work.

PLANNING AND SCHEDULING JOBS

Careful planning is necessary to keep an HT shop running efficiently and productively. Remember that any time lost, whether on a job or between jobs, lowers the overall efficiency of the shop. To keep the work flowing smoothly, you will have to consider such factors as sizing up the job, checking on the availability of materials and supplies, time and material requirements, allowing for priority of work, assigning work, checking the progress of the work, and checking the completed work.

Sizing up the Job

When a new job order comes into the HT shop, check it over carefully to be sure that it contains all the necessary information. Don't start a job until you are sure that you understand in detail the scope of the job. If blueprints or drawings will be needed, check to be sure that they are available. Shipcheck each job as soon

as possible to verify the scope of the job against available blueprints or other technical documentation.

Checking on Materials

Before starting a job, be sure that all the required materials will be available. This means not only the correct kind of wood or metal for the job, but also whatever other materials may be required to finish the job, such as glue, dowels, nails, welding rod, rivets, bolts, clips, and hinges. Ensure that all material used for the repair meets applicable specifications and are verifiable.

Estimating Time for a Job

Accuracy in estimating the required time for a specific job is primarily a matter of experience. When making a time estimate, you will compare the present problem with one you have solved in the past. An estimate, in a very real sense, is a guess, but it is an intelligent guess when based on the proper use of records and experience.

From time to time, you will probably be called upon to give the estimate of the time that will be needed to complete a repair job. For most of the routine jobs coming into the HT shop, a quick estimate made on the basis of your experience will probably be sufficient. For urgent jobs, however, the time required for completion may be an important consideration; and you should be very cautious in making these estimates. The estimate(s) that you make may have an effect on the operational schedule of a ship; therefore, it is important to consider all factors that might affect the time required for the job.

The following steps are generally required to make an accurate estimate of the time that will be required for a repair job.

1. Study the job order and any blueprints or other drawings that are applicable to determine the extent of the job. For a repair job, inspect the damaged item to determine whether or not it requires repairs or replacements in addition to those specified in the job order. In other words, the first thing to do is to get all possible information about the job.

2. Find out the priority of the job. If it has a lower priority than some of the work already scheduled to be done in the shop, you will not be able to start work immediately. Any delay in starting the job must, of course, be added to the total estimate of time required to complete the job.

3. Find out what materials will be required, and make sure they are available. If the specified materials are not available, time may be lost while you try to find a satisfactory substitute.

4. Find out what part of the job (if any) must be done in other shops. It is important to consider not only the time actually required by these other shops, but also the time that may be lost if one of the shops holds up the work of your shop. Never attempt to estimate the time that will be required by other shops. Each shop must make a separate estimate, and these estimates must be combined to obtain the final estimate.

5. Consider all the interruptions that might cause delay, over and above the time actually required for the work itself. Such things as ship's drills, inspections, field days, and working parties will affect the number of personnel that will be available to work on the job at any given time.

6. Next, try to estimate the time that will be required for the work itself. Perhaps the best way to do this is to divide the total job into its various phases or steps that will have to be done. The time required for each step depends partly on the nature of the job and partly on the number of personnel available. You may find it helpful to draw a diagram or chart showing how many persons can be assigned to each step of the job, and how long each step is likely to take. Figure 2-2 shows a chart made up to estimate the total time required to make certain repairs to a gangway.

The total job is divided up into nine phases or steps:

A. Making the template. This step might take one person about 1 hour.

B. Obtaining metal fittings (treads and padeyes). This step might take one person about 1 hour.

C. Renewing one stringer and six treads. This step might take four people about 6 hours.

D. Sanding the surface and using wood filler. This step might take two people about 2 hours.

E. Giving the first coat of varnish. This step might take one person about 1 hour.
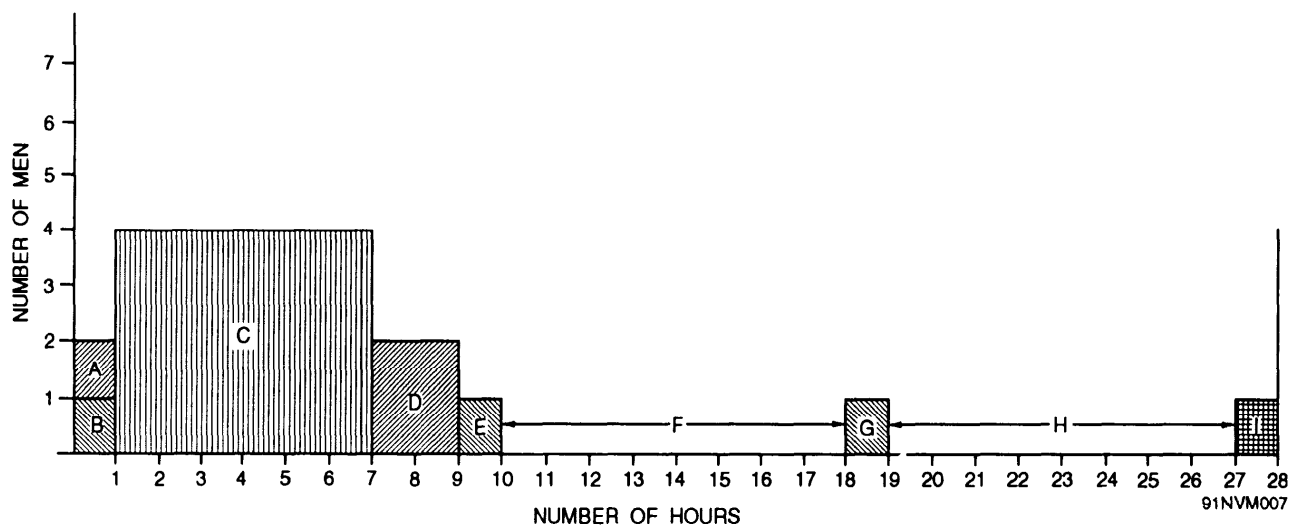
Figure 2-2.—Estimating time required for a gangway repair job.

F. Drying time (8 hours). This must be counted in the total estimate even though no work can be done on the gangway during this period.

G. Giving the second coat of varnish. This step might take one person about 1 hour.

H. Drying time (8 hours).

I. Putting on the metal fittings. This step might take one person about 1 hour.

Notice that, although there are four people available to work on this job, it is not possible for all four to be working on it at all times. Most of the work must be done in sequence; for example, you can't finish the surface before you have renewed the stringer and treads, and you can't make the new stringer and treads before you have made the template. Step A (obtaining the metal fittings) could be performed at any convenient time before step I (putting on the metal fittings). The advantage of using a diagram such as the one shown in figure 2-2 is that it shows at a glance the total number of hours that must be allowed for the work-in this case, 28 hours.

The diagram shows you something else, too: the number of man-hours required for each step. Let's add these up:

STEP A	1 man-hour
STEP B	1 man-hour
STEP C	24 man-hours
STEP D	4 man-hours
STEP E	1 man-hour
STEP F	0 man-hour
STEP G	1 man-hour
STEP H	0 man-hour
STEP I	1 man-hour
TOTAL =	33 man-hours

So you find that the total job requires 33 man-hours of work. But what does this mean? Does the number of man-hours tell you how long the job is going to take? Is it safe to assume that a job requiring 33 man-hours can be done in 8 1/4 hours if you put four people to work on it? Obviously not, since there is a limit to the number of people who can work on the job at any given time.

The unit MAN-HOURS, then, is a measure of amount of work but not of total length of time. You should be very cautious about using man-hours when estimating how long a job will take, since this measure does not allow for the sequence in which the work must be performed, the number of steps required, or the number of people who can work on the job at each step.

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Material Estimates

The material you will use on a given job will be determined from specifications or plans. If the material is not specified, you will decide what you need and select it. Your decision will be based on the purpose of the structure or object, and the conditions that it will meet in service. Some of the "in-service conditions" are resistance to corrosion, resistance to acids, or resistance to wear. You will have to consider the weight to be supported, pressures to be withstood, and working stresses that may be encountered. Safety, too, is an important point to consider in determining the material to use on a particular job. There is no set rule to follow. Each problem must be considered individually.

ALLOWING FOR WASTE.—In most jobs, a careful study of the detail plans will reveal the exact amount of material needed for a particular installation or repair. However, it is sometimes impossible to use every linear foot of a length of pipe or bar stock or to use every square foot of plate or sheet metal. Some waste is unavoidable, and an allowance for such waste is necessary in material estimates.

WEIGHT CONSIDERATIONS.—Weight considerations are important in shipboard repairs and alterations. Consequently, it not only may be necessary for you to determine the amount of material required for a job, but also to calculate the weight of the material going into the job. The weight of pipes, tubes, plates, sheets, and bars can be determined in either of two ways: (1) by referring to tables in a handbook and locating the weight per linear or square foot of the particular material in question; and (2) by arithmetical computation. For example, suppose you need to know the weight of a 30-foot length of 2 1/2-inch extra strong steel pipe. By referring to the appropriate table in a piping handbook, we find that this pipe weighs approximately 7.66 pounds per linear foot. Thus, a 30-foot length weighs 229.8 pounds.

But, suppose you do not have such tabulated information available. In that case, it is necessary to determine the volume of metal involved and multiply that result by the weight of the metal per cubic inch. To compute the volume of metal in a pipe or tube, think of it as being two cylinders. The outside diameter being cylinder 1 and the inside diameter being cylinder 2. The result obtained by subtracting the volume of cylinder 2 from the volume of cylinder 1 will be the volume of metal (in cubic inches) contained in the pipe or tube. The volume of a cylinder is equal to the area of the base times the height ($\pi R^2 H$. For example, to compute the weight of the 2 1/2-inch extra strong steel pipe shown in figure 2-3, you would use the following procedure:

Step 1. Compute the volume of metal contained in cylinder 1, using the formula volume = $\pi R^2 H$. Substituting known values we find that:

$$\pi = 3.1416$$

$$R = 1.4375$$

$$H = 30 \text{ ft (360 inches)}$$

$$V = 3.1416 \, (1.4375)^2 360$$

$$V = 2337.0 \text{ cu in.}$$

Step 2. Compute the volume of metal contained in cylinder 2:

$$\pi = 3.1416$$

$$R = 1.1615$$

$$H = 30 \text{ ft (360 inches)}$$

$$V = 3.1416 \, (1.1615)^2 360$$

$$V = 1525.7 \text{ cu in.}$$
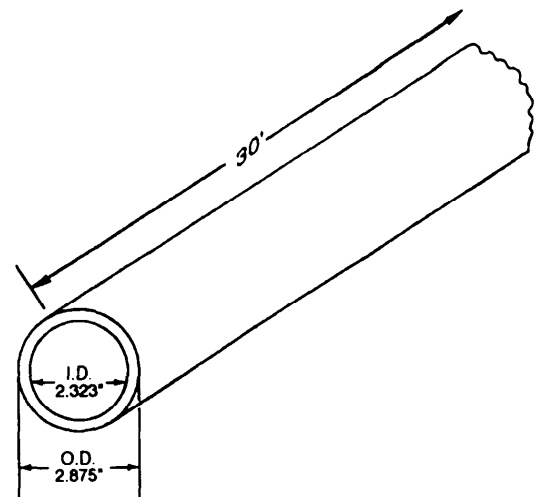
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Figure 2-3.—Actual measurements of inside and outside diameters of 2 1/2-inch extra strong steel pipe.

Step 3. Find the volume of metal contained in the pipe by subtracting the volume of cylinder 2 from the volume of cylinder 1:

$$2337.0 - 1525.7 = 811.3 \text{ cu in.}$$

Step 4. Find the weight of the pipe by multiplying the volume of metal by the weight of steel, shown in table 2-1:

$$811.3 \times 0.284 = 230.4 \text{ lb}$$

The weight of plate and sheet metal structures may be found by computing the volume of metal contained (in cubic inches), and then multiplying the volume by the weight of the metal (per cubic inch), as shown in table 2-2. As an example, find the weight of a steel plate that is 68 inches in length, 44 inches wide and 1/2 inch thick. Using the formula weight = volume × weight of the metal per cubic inch, we use the following procedure:

Step 1. Compute the volume of metal contained.

$$\text{Volume} = \text{length} \times \text{width} \times \text{thickness}$$

$$V = 68 \times 44 \times 1/2$$

$$V = 1496 \text{ cu in.}$$

Step 2. Find the weight of the steel plate.

$$\text{Weight} = \text{volume of metal} \times \text{weight per cu in.}$$

$$W = 1496 \times 0.284$$

$$W = 424.86 \text{ lb}$$

Table 2-1.—Weight of Common Metals

Material	Pounds per cubic inch
Aluminum	0.098
Yellow brass	0.307
Naval brass	0.304
Copper-nickel	0.323
Cast iron	0.258
Steel	0.284
Lead	0.4106
Copper	0.321
Tin	0.265

Table 2-2.—Weight of Various Gauges of Uncoated Plain Steel Sheet Metal

Gauge	Decimal thickness (inches)	Weight (pounds per square foot per indicated thickness)
11	0.1196	4.89
12	0.1046	4.28
13	0.0897	3.67
14	0.0747	3.06
16	0.0598	2.45
18	0.0478	1.95
20	0.0359	1.47
22	0.0299	1.22
24	0.0239	0.98
26	0.0719	0.73
28	0.0149	0.61
30	0.0120	0.49

The weight of steel per square foot may be determined by multiplying the thickness of the metal by 40.9. Table 2-2 lists the weight per square foot of the various gauges of uncoated plain steel sheet metal, and also the decimal equivalents of the different gauges.

Obviously, to calculate the weight of a particular structure, you must be able to break the whole down into its component geometrical parts, circles, squares, rectangles, pyramids, and so on, and determine their respective volumes. Further, you need to know the weight of metal per cubic inch. This information can be found in a variety of handbooks readily available in the engineer or repair department office. Table 2-1 gives the information for a few of the more common metals.

When specific job requirements are known, estimating of material needed is no problem. However, when estimating requirements for future use, you will have to anticipate your needs. Referring to records of previous jobs and records of materials expended can help eliminate much guesswork.

Priority of Work

In scheduling work in an HT shop, you will have to consider the priority of each job. Most job orders will have a ROUTINE priority; this means that they must be done as soon as possible, within the normal capacity of the shop. Jobs having an URGENT priority must be

done immediately, even at the expense of routine jobs that may be in progress. Jobs with a DEFERRED priority do not constitute a problem, since they are usually accomplished when the workload of the shop is light and there are no routine or urgent jobs to be done.

Assigning Work

The assignment of work in the HT shop is extremely important. As a rule, the more complicated jobs should be assigned to the more experienced personnel. When time and the workload of the shop permit, however, the less experienced personnel should be given difficult work to do under proper supervision so that they may acquire skill and self-confidence.

When assigning work, be sure that the person who is going to do the job is given as much information as necessary. An experienced person may need only a drawing and a general statement concerning the finished product. A less experienced person will probably require additional instructions concerning the layout of the job and the procedures to be followed.

Checking Progress of Work

When you are in charge of the HT shop, you will have to keep a constant check on the progress of all work. In particular, be sure that the proper materials are being used, that the work is set up properly, that personnel are using the correct tools properly, and that all safety precautions are being observed. Note the progress of each job in relation to the planned schedule of work; you will probably find that some jobs are ahead of schedule, while others are lagging behind. If necessary, reschedule the work to prevent the development of bottlenecks. By frequently talking to shop personnel and answering their questions, you can prevent jobs from being spoiled, as might happen if you were not available to give correct details on the jobs.

Checking Completed Work

When you are in charge of the HT shop, it will be your responsibility to inspect and approve all finished work before it is allowed to leave the shop. In addition, you must make sure that all shop records concerning finished work are complete, correct, and up to date.

SHOP MATERIALS

In all probability, your first experience with naval supplies and repair parts was as a member of a store's working party. At that time, however, you probably did not understand "how" or "why" the stores were placed aboard. As a HTI or HTC, you are expected to know the immediate supply channels in order to obtain the material you need. The fact that there are supply specialists aboard does not relieve you of the responsibility for aiding in procuring, handling, stowing, and accounting for the materials used in your shop.

The big job of supply is handled by the supply department. But if that department does not know what you need, you are not going to have the material you want when you need it. It is your responsibility to keep the proper people informed of your estimated needs so that you will have the required materials on board at all times. Most of your orders will be placed through your division officer or the head of the department, but in some cases, you may order directly from the supply officer.

Selecting Materials and Repair Parts

The materials and repair parts to be used are specified for many jobs, but not for all. When materials or parts are not identified in the instructions accompanying the job, you will have to use your own judgment or do some research to find out just what material or part should be used. When you must make the decision yourself, select the material on the basis of the purpose of the structure or part and the service conditions it must withstand. Operating pressure and operating temperature must be considered in selecting materials. For some applications, wear resistance or corrosion resistance will be important; for others (as, for example, for high-temperature steam piping), creep resistance will be a necessary property of the material.

The shipboard sources of information that will be helpful to you in identifying or selecting materials and repair parts include (1) nameplates on the equipment, (2) manufacturers' technical manuals and catalogs, (3) stock cards maintained by the supply officer, (4) specifications for ships, (5) ship's plans, blueprints, and other drawings, and (6) allowance lists.

NAMEPLATES on equipment supply information regarding the characteristics of the equipment, and are therefore a useful source of information concerning the equipment itself. Nameplate data seldom, if ever, include the exact materials required for repairs; however, the information given on the characteristics of the equipment may be a useful guide for the selection of materials.

MANUFACTURERS' TECHNICAL MANUALS are furnished with practically all machinery and equipment on board ship. Materials and repair parts are sometimes described in the text of these technical manuals; usually, details of materials and parts are given on the drawings. Manufacturers' catalogs of repair parts are sometimes furnished with shipboard equipment.

The set of STOCK CARDS that is maintained by the supply officer is often a valuable source of information for the identification of repair materials and repair parts. One of these cards is maintained for each machinery repair part carried on board.

SHIP'S PLANS, BLUEPRINTS, and other drawings available on board ship are excellent sources of information on materials and parts to be used in making various repairs. Many of these plans and blueprints are furnished in regular large sizes; some drawings are being furnished on microfilm to naval shipyards and to repair ships and tenders.

Handling Materials and Equipment

As an HT, your duties will include the supervision of the handling, stowing, and inventory of all shop materials and repair parts. The rigging and actual transferring of the materials, parts, and equipment to your ship will be done under the supervision of the Boatswain's Mate. It is your responsibility to furnish the personnel and supervise the stowage of the materials or equipment in the proper shop stowage space.

Heavy plate is usually handled with wire rope slings or straps or with an approved-plate clamp such as the one shown in figure 2-4. These clamps should NOT be used for handling bundles of sheet metal, since the sheets in the middle could slip and cause the entire load to drop. Bulky items such as bars, strap, and structural shapes are usually handled with slings or straps. The chokers shown in figure 2-5 are effective devices for handling pipe and other materials that must be gripped tightly; when the hooks are used in pairs, the pull should be from opposite sides of the load, as shown in figure 2-5.

STOWAGE.—Whenever possible, repair parts should be stowed in special storerooms. On small ships, where it may be impracticable to stow repair parts boxes in storerooms, the boxes are generally located in (or near) the same space as the machinery for which they are required. Where the supply department has
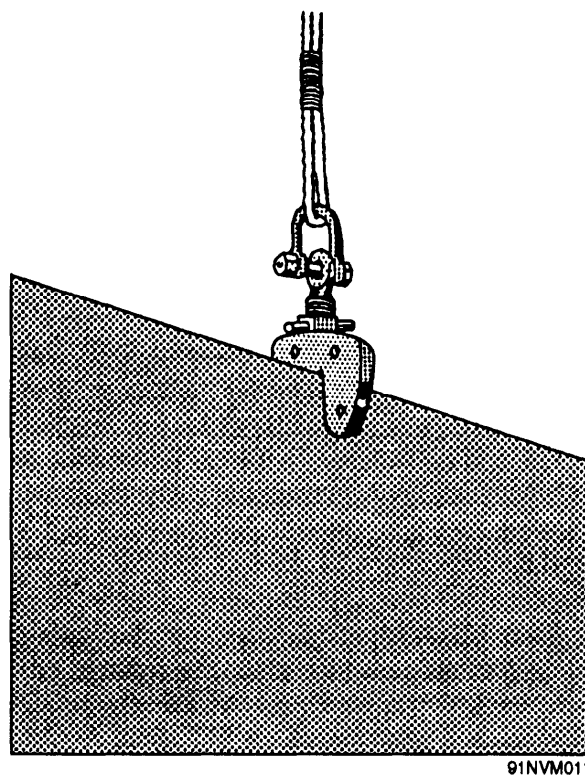
Figure 2-4.—Clamp for handling heavy plate.
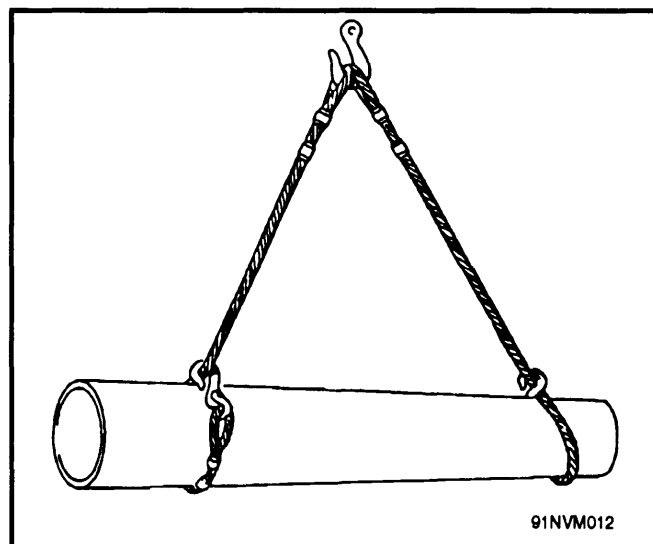
Figure 2-5.—Chokers for handling pipe.

custody of repair parts, storerooms with bins and drawers for individual stowage of repair part items are generally used instead of the repair parts boxes. The available space and the type of work done in the shop are factors that determine how much material is stowed in the shops and how much is stowed in storerooms.

Pipe Shop Stowage.—In a tender or repair ship pipe shop, for example, you will probably not have

room for all the varied sizes and lengths of materials that you may use. However, storage should be provided in the pipe shop for the most commonly used pipe sizes and also for the leftover lengths that accumulate in the course of time. Overhead or bulkhead storage racks are often used for stowage of piping. Stowage should be provided in the pipe shop for the most commonly used valves, fittings, bolts, nuts, rivets, and other items required for piping repairs.

Weld Shop Stowage.—In a welding shop, you will have the problem of stowing welding machines, welding rods, protective equipment, and all the other gear required for welding. Particular precautions should be taken in stowing electrodes to make sure that they will be kept dry and that the coated surfaces will not be chipped.

Sheet Metal Shop Stowage.—In the sheet metal shop and in the shipfitter shop, the stowage of large sheets, bars, or structural shapes will present special problems. In a general-purpose HT shop, the requirements vary so much from day to day that you will probably find it impracticable to stow large amounts of any one material; instead, you will draw your material as you need it from a storeroom. The main stowage problem that you are likely to have in a general-purpose HT shop is the stowage of leftover materials.

STOWAGE REQUIREMENTS.—No matter what type of shop you are in, certain general rules apply to the stowage of material and equipment. Some of thest important of these are as follows:

● Stow material neatly and in such a way that you can get it when you need it.

● Identify all materials. A piece of carbon molybdenum steel looks just like a piece of mild steel, but you cannot use the two materials for the same purpose. Materials should be identified by labels for each bin or rack, by shipping tags attached to the materials, by color-code markings (when applicable), and by stock number. Keeping the stock number with the material will save you time and trouble when you need to reorder material.

● Protect all materials against rust and other corrosion and against other kinds of damage.

● Be sure that your stowage facilities include provision for securing for sea. Metal sheets, bars, structural shapes, pipes, and tubes must be secured so that they will not shift when the ship is underway. Padeyes, turnbuckles, wedges, bars, and C-clamps can be used to secure materials.

● Within the limits of available space, provide stowage facilities that will make the shop a convenient place to work.
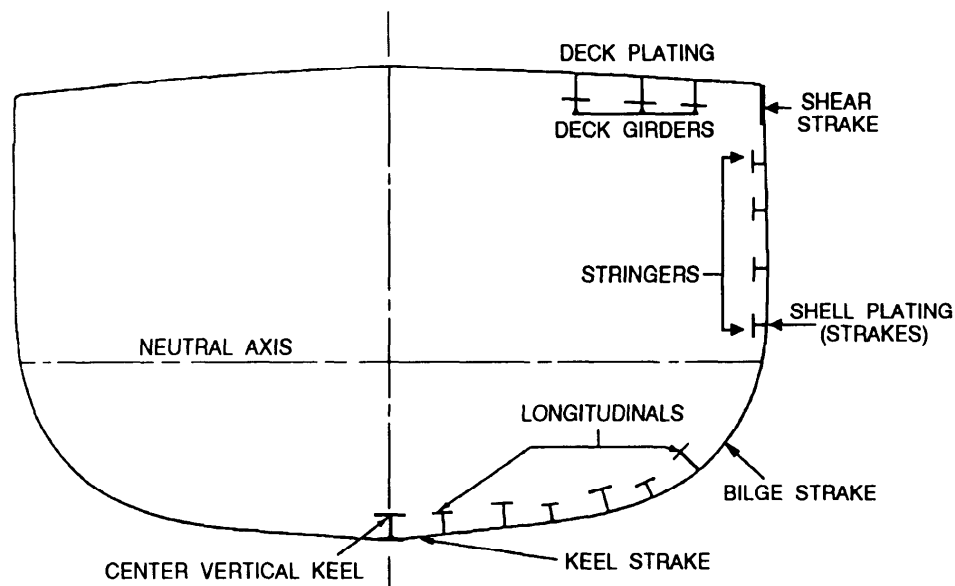
Figure 2-6.—Shell section of a destroyer.

HULL MEMBERS

In the repair of ships, it is important that you have an understanding of basic ship structure. Therefore, the following section will discuss the structural parts of a ship and the purpose of the parts.

The principal strength members of the ship's structure are located at the top and bottom of the hull where the greatest stresses occur. The top section includes the main deck plating, the deck girders, and the sheer strakes of the side plating. The bottom section includes the keel, the outer bottom plating, the inner bottom plating, and any continuous longitudinals in way of the bottom. The side webs of the ship girder are composed of the side plating, aided to some extent by any long, continuous fore-and-aft bulkheads. Some of the strength members of a destroyer hull girder are indicated in figure 2-6.

KEEL

The keel is the most important structural member of a ship. It is considered to be the backbone of the ship. The keel is built up of plates and angles into an I-beam shape (fig. 2-7). The lower flange of this I-beam structure is the flat keel plate, which forms the center strake of the bottom plating. (On large ships, an additional member is attached to this flange to serve as the center strake.)
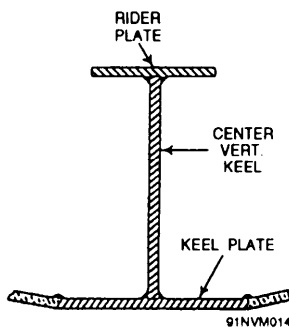
The web of the I-beam is a solid plate that is called the vertical keel. The upper flange is called the rider plate; this forms the center strake of the inner bottom plating. An inner vertical keel of two or more sections, consisting of I-beams arranged one on top of the other, is found on many large combatant ships.

FRAMING

Frames used in ship construction may be of various shapes. Frames are strength members. They act as integral parts of the ship girder when the ship is exposed to longitudinal or transverse stresses. Frames stiffen the plating and keep it from bulging or buckling. They act as girders between bulkheads, decks, and double bottoms, and transmit forces exerted by load weights and water pressures. The frames also support the inner and outer shell locally and protect against unusual forces, such as those caused by underwater explosions. Frames are called upon to perform a variety of functions, depending upon the location of the frames in the ship. Figure 2-8 shows various types of frames used on board ship.

There are two important systems of framing in current use:the transverse framing system and the longitudinal framing system. The transverse system provides for continuous transverse frames with the widely spaced longitudinals intercostal between them. Transverse frames are closely spaced and a small number of longitudinals are used. The longitudinal system of framing consists of closely spaced longitudinals, which are continuous along the length of the ship, with transverse frames intercostal between the longitudinals.

Transverse frames are attached to the keel and extend from the keel outward around the turn of the bilge and up to the edge of the main deck. They are closely spaced along the length of the ship, and they define the form of the ship.

Figure 2-7.—Typical welded keel section.
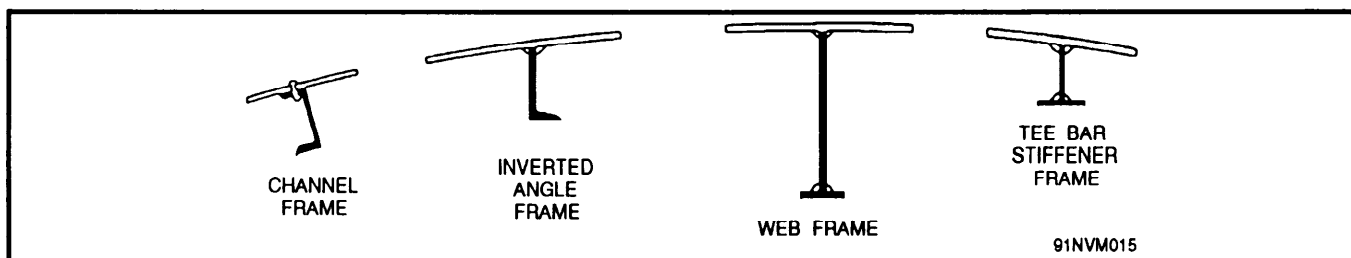
Figure 2-8.—Types of frames used on board ship.

Longitudinals (fig. 2-9) run parallel to the keel along the bottom, bilge, and side plating. The longitudinals provide longitudinal strength, stiffen the shell plating, and tie the transverse frames and the bulkheads together. The longitudinals in the bottom (called side keelsons) are of the built-up type (fig. 2-10).

Where two sets of frames intersect, one set must be cut to allow the other to pass through. The frames,
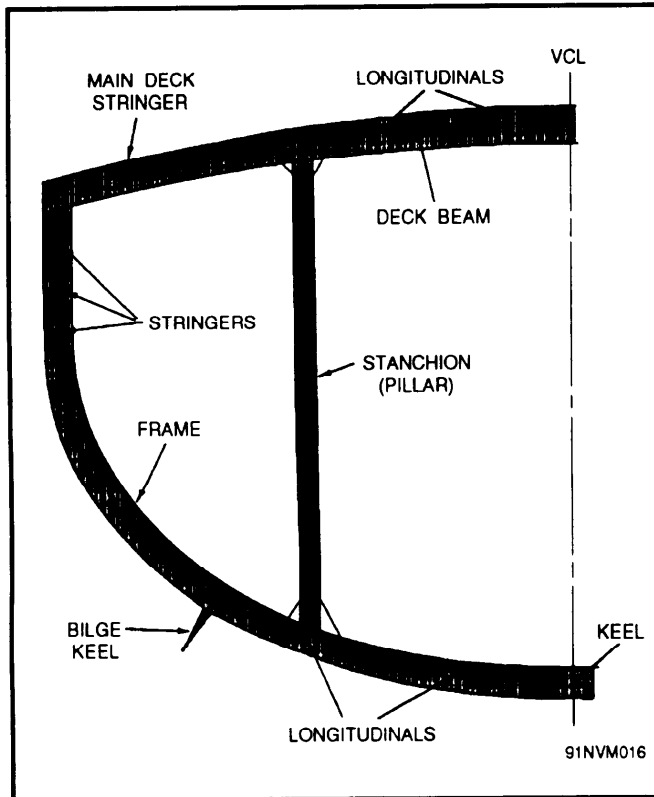
Figure 2-9.—Basic frame section (longitudinal framing).
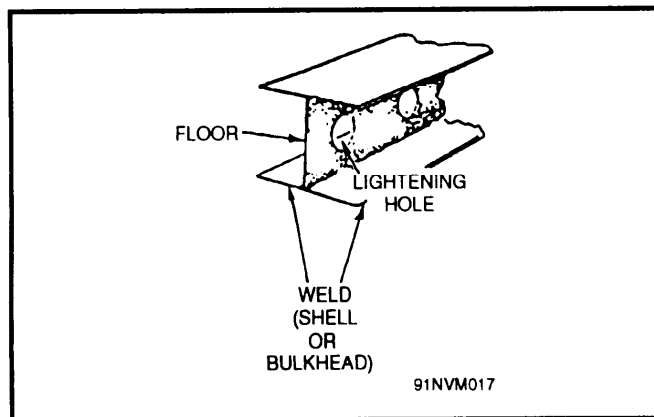
Figure 2-10.—Built-up longitudinal.
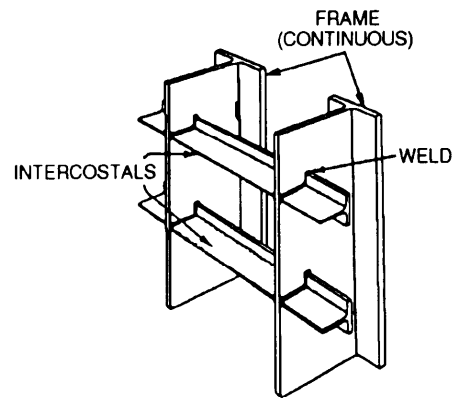
Figure 2-11.—Intercostal and continuous frames.

which are cut and thereby weakened, are known as intercostal frames; those that continue through are called continuous frames. Both intercostal and continuous frames are shown in figure 2-11.

A cellular form of framing results from a combination of longitudinal and transverse framing systems using closely spaced deep framing. Cellular framing is used on most naval ships.

In the bottom framing, which is normally the strongest portion of the ship's structure, the floors and keelsons are integrated into a rigid cellular construction (fig. 2-12). Heavy loads, such as the ship's propulsion machinery, are bolted to foundations that are built directly on top of the bottom framing (fig. 2-13). (This method is outdated and is being replaced by block assembly technology.)

In many ships, the top of this cellular region is covered with shell plating, which forms many tanks or voids in the bottom of the ship. The plating over the intersection of the frames and longitudinals is known as the inner bottom plating. The inner bottom plating is a watertight covering laid on top of the bottom framing. It is a second skin inside the bottom of the ship. It prevents flooding in the event of damage to the outer bottom, and it also acts as a strength member. The tanks and voids may be used for stowage of fresh water or fuel oil or they can be used for ballasting. This type of bottom structure, with inner bottom plating, is called double-bottom construction.

BOW AND STEM CONSTRUCTION

The ship's bow, which is the front of the ship, varies in form from one type of ship to another as the requirements of resistance and seakeeping dictate the

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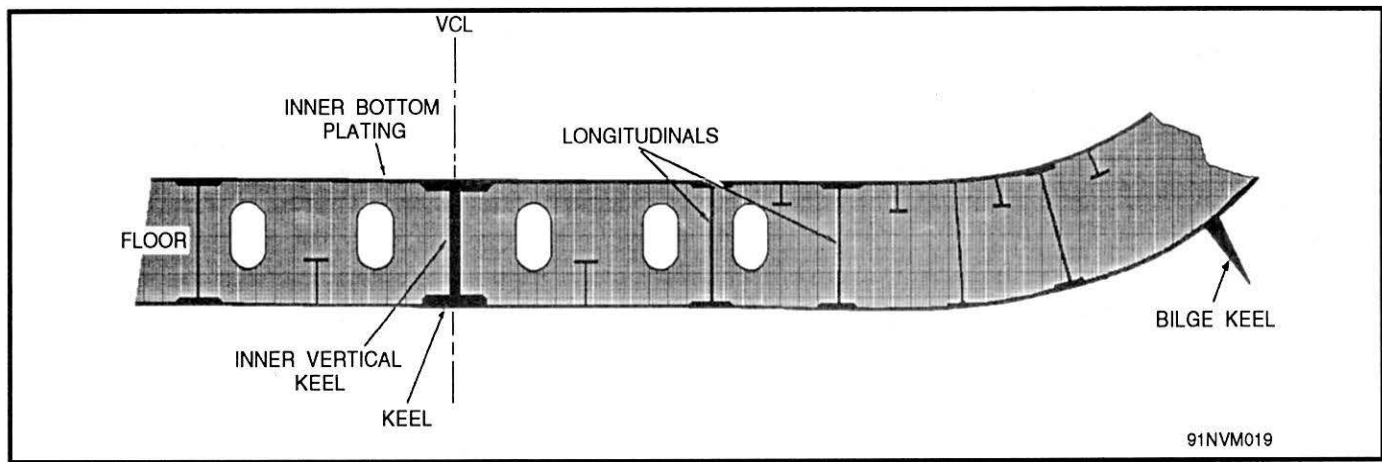
Figure 2-12.—Bottom structure.
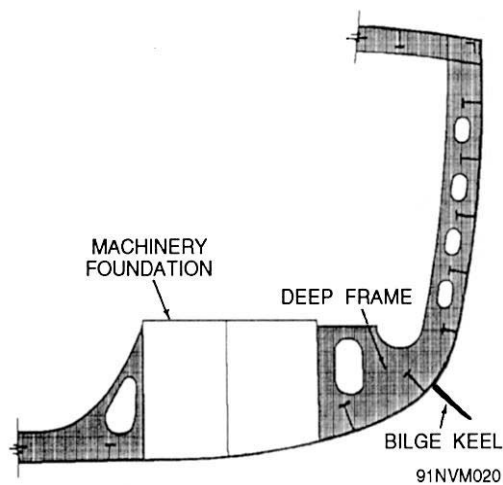
Figure 2-13.—Deep floor assembly for machinery foundations.

shape. The external shape is shown in figure 2-14 and is commonly used on combatant ships. This form is essentially bulbous at the forefoot, tapering to a sharp entrance near the waterline and again widening above the waterline. Internally, the stem assembly has a heavy centerline member that is called the stem post. The stem post is recessed along its after edge to receive the shell plating, so that the outside presents a smooth surface to cut through the water. The keel structure is securely fastened to the lower end of the stem by welding. The stem maintains the continuity of the keel strength up to the main deck. The decks support the stem at various intermediate points along the stem structure between the keel and the decks.

At various levels and at regular intervals along the stem structure between the keel and the decks are horizontal members called breast hooks. Breast hooks rigidly fasten together the peak frames, the stem, and the outside plating. Breast hooks are made of heavy plate and are basically triangular in shape.

Deep transverse framing and transverse bulkheads complete the stem assembly. The stem itself is fabricated from castings, forgings, and heavy plate, or in the case of smaller ships, heavy, precut structural steel plate.

STERN STRUCTURE

The after-most section of the ship's structure is the stem post, which is rigidly secured to the keel, shell plating, and decks. On single-screw ships, the stem post is constructed to accommodate the propeller shaft and rudder stock bosses. The stem post as such is difficult to define, since it has been replaced by an equivalent structure of deep framing. This structure (fig. 2-15) consists of both longitudinal and transverse framing that extends throughout the width of the bottom in the vicinity of the stem. To withstand the static and dynamic loads imposed by the rudders, the stem structure is strengthened in the vicinity of the rudder post by a structure known as the rudder bearing housing.

PLATING

The outer bottom and side plating forms a strong, watertight shell. Shell plating consists of approximately rectangular steel plates arranged longitudinally in rows or courses called strakes. The strakes are lettered, beginning with the A strake, which is just outboard of the keel, and working up to the uppermost side strake.
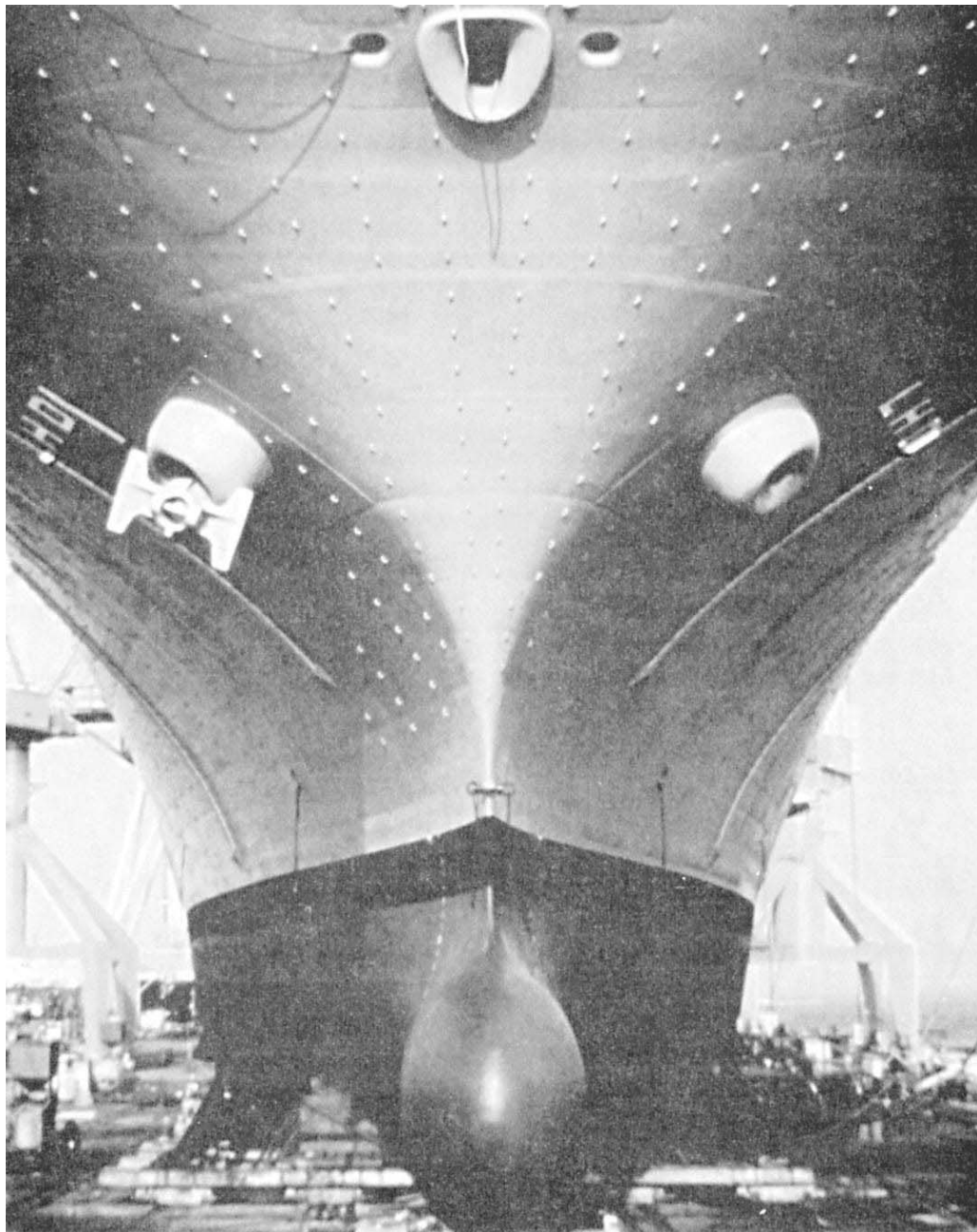
Figure 2-14.—Bulbous-bow configuration.

The end joint formed by adjoining plates in a strake is called a butt. The joint between the edges of two adjoining strakes is called a seam. Seams are also welded flush. Butts and seams are illustrated in figure 2-16.

In general, seams and butts are located so that they do not interfere with longitudinals, bulkheads, decks, and other structural members. Since the hull structure is composed of a great many individual pieces, the strength and tightness of the ship as a whole depend very much upon the strength and tightness of the connections between the individual pieces. In today's modern naval vessels, joints are welded flush together to form a smooth surface.

BILGE KEELS

Bilge keels are fitted in practically all ships at the turn of the bilge. Bilge keels extend 50 to 75 percent of the length of the hull. Bilge keels consist of two plates forming a "V" shape welded to the hull, and on large

Figure 2-15.—Stern Structure.

Figure 2-16.—Section of a ship, showing plating and framing.

2-25

ships may extend out from the hull nearly 3 feet. Bilge keels serve to reduce the extent of the ship's rolling.

DECKS

Decks provide both longitudinal and transverse strength to the ship. Deck plates, which are similar to the plates used in side and bottom shell plating, are supported by deck beams and deck longitudinales.

The term uppermost strength deck is applied to the deck that completes the enclosure of the box girder and the continuity of the ship's structure. It is the highest continuous deck—usually the main or weather deck. The term strength deck also applies to any continuous deck that carries some of the longitudinal load. On destroyers, frigates, and similar ships in which the main deck is the only continuous high deck, the main deck is the strength deck. The flight deck is the uppermost strength deck on aircraft carriers (CVs and LHDs) that carry helicopters, but the main or hangar deck is the strength deck on older types of carriers.

The main deck is supported by deck transverses and deck longitudinales. Deck transverses are the transverse members of the framing structure. The transverse beams are attached to and supported by the frames at the sides, as shown in figure 2-17. Deck girders are similar to longitudinales in the bottom structure in that they run fore and aft and intersect the transverse beams at right angles.

The outboard strake of deck plating that connects with the shell plating is called the stringer strake. The stringer strake is usually heavier than the other deck strakes, and it serves as a continuous longitudinal stringer, providing longitudinal strength to the ship's structure.

STANCHIONS

To reinforce the deck transverses and to keep the deck transverse brackets and side frames from carrying the total load, vertical stanchions or columns are fitted between decks. Stanchions are constructed in various ways of various materials. Some are made of pipe or rolled shapes. The stanchion shown in figure 2-18 is in fairly common use; this pipe stanchion consists of a steel tube that is fitted with special pieces for securing it at the upper end (head) and at the lower end (heel).

BULKHEADS

Bulkheads are the vertical partitions that, extending athwartships and fore and aft, provide compartmentation to the interior of the ship. Bulkheads may be either structural or nonstructural. Structural bulkheads, which tie the shell plating, framing, and decks together, are capable of withstanding fluid pressure; these bulkheads usually provide watertight compartmentation. Nonstructural bulkheads are lighter; they are used chiefly for separating activities aboard ship.

Bulkheads consist of plating and reinforcing beams. The reinforcing beams are known as bulkhead stiffeners (fig. 2-19). Bulkhead stiffeners are usually placed in the

Figure 2-17.—Transverse beam and frame.
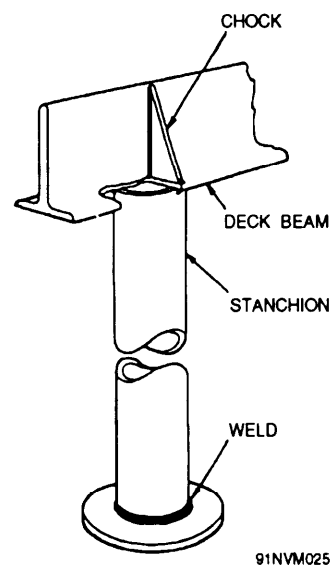
Figure 2-18.—Pipe stanchion.
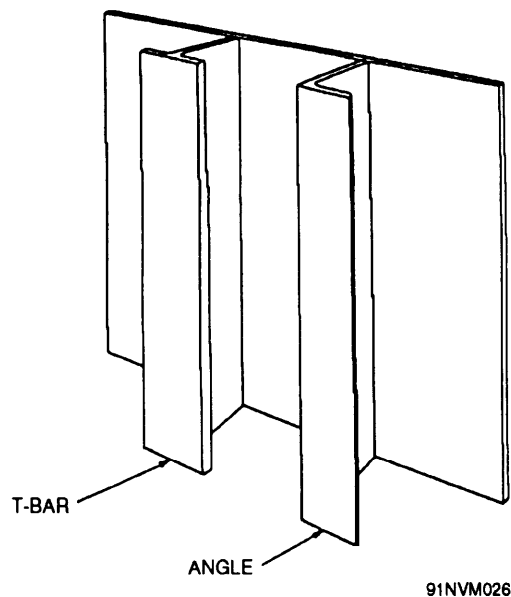
Figure 2-19.—Bulkhead stiffeners.

vertical plane and aligned with deck longitudinales; the stiffeners are secured at top and bottom to any intermediate deck by brackets attached to deck plating. The size of the stiffeners depends upon their spacing, the height of the bulkhead, and the hydrostatic pressure that the bulkhead is designed to withstand.

Bulkheads and bulkhead stiffeners must be strong enough to resist excessive bending or buckling in case of flooding in the compartments that they bound. To form watertight boundaries, structural bulkheads must be joined to all decks, shell plating, bulkheads, and other structural members with which they come in contact. Main subdivision bulkheads extend through the watertight volume of the ship, from the keel to the bulkhead deck, and serve as flooding boundaries in the event of damage below the waterline.

SUMMARY

Ship repair is the fundamental duty of the Hull Maintenance Technician. In this chapter, you have been exposed to the basic organization of the IMA and some of the personnel assigned to this type of organization. You have also been exposed to the basics of the QA program and its link to maintenance. When assigned to your command you should study your command's organization and QA program for a greater understanding of your role in that organization. As you gain experience and advance in rate you will be given the opportunity to become a work center supervisor. The appointment as a work center supervisor carries a lot of responsibility and accountability for your actions. But the role of a work center supervisor is often a rewarding and challenging position. As a work center supervisor you will be expected to organize, plan, and supervise the completion of various tasks that met all the requirements of the QA program.

CHAPTER 3

WOODWORKING CUTS AND JOINTS

LEARNING OBJECTIVES

Upon completion of this chapter, you should be able to do the following:

● *Identify, the various characteristics of wood, and tree growth and structure.*

● *Identify the various methods used in cutting and seasoning lumber.*

● *Identify common defects and blemishes of lumber.*

● *Identify the various grades of lumber and the methods used to measure lumber.*

● *Identify types of wood joinery to include cuts, joints, fasteners, and materials.*

● *Recognize the proper method and necessary took and equipment for laying out and cutting joints.*

● *Identify applications for the various joints.*

● *Recognize the purpose and use of different types of fastening materials.*

● *Identify the types of glue and their application methods.*

● *Identify the various sanding materials and their proper uses.*

INTRODUCTION

Although Navy ships are now made largely of steel and other metals, there is still plenty of woodworking for HTs to do. Cruisers and carriers usually have a shop equipped with the necessary handtools and three or more standard woodworking machines; tenders and repair ships have large shops with all types of woodworking machines.

An HT is required to have a knowledge of the types of wood and woodworking glue, the principles of wood finishing, and to be able to solve problems dealing with the number of board feet in a piece of lumber. This chapter provides information related to these requirements.

WOOD

In the lumber industry, woods are classified as hardwoods or softwoods. These two terms are more as a matter of convenience than as an exact classification. In fact, this classification does not depend on how hard the wood is. It depends on what kind of leaves the trees have. If the tree has broad leaves that shed in winter, the wood is classified as hardwood. If the tree has needle leaves and cones, the wood is classified as softwood. These classifications are somewhat confusing because some softwoods are harder than some hardwoods, and some hardwoods are softer than most softwoods.

Hardwoods are used in construction and repair work because of their strength, durability, and ability to resist warpage. They are used to make furniture, dowels, and some patterns. Hardwoods include ash, birch, beech, white oak, poplar, walnut, and maple.

HTs prefer softwoods for most patterns because they work easily. Softwoods are also used as structural lumber, boat planking, and for shoring. Softwoods include white cedar, cypress, Douglas fir, white pine, yellow pine, and redwood.

TREE GROWTH AND STRUCTURE

Wood consists of small cells. The size and arrangement of these cells determine the grain of the wood and many of its properties. Look at a freshly cut tree stump. You will see thousands of large and small cells arranged in circular rings around the pith or center of the tree. The large cells have thin walls, and the smaller cells have thick walls (figs. 3-1 and 3-2). Rings form because of a difference in the growth rate during various seasons of the year. In spring, a tree grows rapidly and builds up a layer of soft, large cells. These cells appear in the cross section of the trunk as the light-colored rings (spring rings).

As the weather gets hotter during early summer, the growth rate slows. The summer cells form closer together and become dark rings (summer rings). The age of a tree can be determined very accurately by counting these dark rings. Some trees, such as oak and walnut, have very distinctive rings. White pine is so uniform that you can barely see the rings.

The sapwood of a tree is the outer section of the tree between the heartwood (darker center wood)

Figure 3-2.—Structure of wood.

and the bark (fig. 3-1). Sapwood is lighter in color than heartwood.

The cambium layer (fig. 3-1) is the boundary between the sapwood and the bark. New sapwood cells form in this thin layer.

Medullary rays (fig. 3-1) are radial lines of wood cells. They are highly visible. Their function is to move cell liquids horizontally in the tree trunk. When speaking of medullary rays, we use thickness to refer to the horizontal dimension, and width to refer to the vertical dimension.

When a tree is sawed lengthwise, the annual rings form a pattern called the *grain.* Several terms describe wood grain.

● If the wood cells that form the grain are closely packed and small, the wood is *fine-grained* or *close-grained.* Maple and birch are good examples.

● If the cells are large and porous, the wood is *coarse-grained* or *open-grained.* Oak, walnut, and mahogany are examples of coarse-grained wood.

● When the wood cells are straight and parallel to the trunk of the tree, the wood is *straight-grained.*

● If the grain is crooked, slanting, or twisted, the wood is *cross-grained.*

Figure 3-1.—Cross section of a tree.

3-2

When a log is sawed lengthwise into boards, each saw cut crosses the annual rings at an angle. If the angle between the saw cut and the rings is 45° or greater, the board has a vertical grain. If the angle is less than 45°, the board has a flat grain. If the log feeds through without turning, the first few outside boards cut off will be flat-grained. The boards cut from the center section will be vertical-grained. The last few boards cut will be flat-grained. By turning the log between saw cuts (fig. 3-3), you can produce all vertical-grained or all flat-grained lumber.

Vertical-grained wood resists wear better than flat-grained wood of the same species. Most flat-grained wood will take and hold a finish better than most vertical-grained wood. Use the term *texture* to express the relative size of the pores (cells) and fibers as coarse or fine textured and even or uneven textured.

CUTTING LUMBER

In a large lumber mill, logs are processed into lumber with huge band saws and circular saws. The two methods of sawing the logs are slash cutting and rift cutting (fig. 3-4). Slash cutting is from a series of parallel cuts. If hardwoods are cut, the process is termed *plain sawing*. If softwoods are cut, the process is termed *flat-grain sawing*.

Slash cutting is the easier, quicker, and less wasteful of the two methods. The surface knots that appear in slash-cut lumber affect the strength of the lumber much less than the knots that appear in rift-cut lumber. However, if a log is sawed to produce all slash-cut lumber, more boards will have knots than if the log were all rift cut.

Rift-cut lumber provides edge grain on both faces. If hardwood is rift cut, it is quarter-sawed lumber. If softwood is rift cut, it is edge-grain lumber. When an entire log is slash cut, several boards near the center of the log will actually be rift cut.

Getting as many edge-grained boards as possible from a tree requires that the logs first be sawed into quarters (fig. 3-3). Then, each quarter is sawed into planks by one of the four methods shown. The method used depends on the intended use for the lumber. Radial quarter sawing will yield lumber that is stronger and will warp less than that gotten by any other method of sawing. The disadvantages, however, are that this method is more costly, takes longer, and is more wasteful of material.

SEASONING LUMBER

Once lumber has been sawed, it must be seasoned (dried). The purpose of seasoning is to remove the moisture from the cells. Moisture (water or sap) occurs in two separate forms—free water and imbibed water. Free water is the moisture the individual cells contain internally. Imbibed water is the moisture contained by the cell walls. During drying or seasoning, the free water evaporates until a minimum remains. The amount of moisture remaining is the fiber-saturation point.

Figure 3-3.—Four methods of quarter sawing.
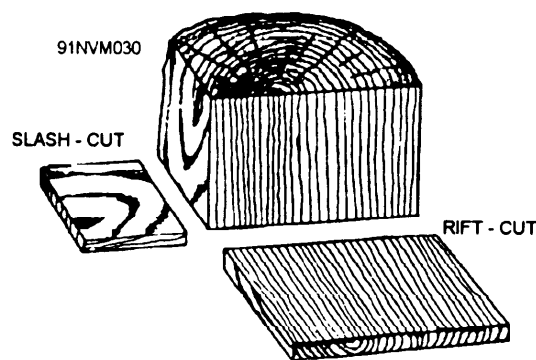
Figure 3-4.—Slash cutting and rift cutting.

The fiber-saturation point varies from 25 to 30 percent, but for general purposes is accepted as 30 percent. Below the fiber-saturation point, the imbibed water extracts from the cell walls, causing a reduction in the thickness of the walls.

Wood shrinks across the grain when the moisture content lowers below the fiber-saturation point. Evaporation or absorption of moisture causes shrinking and swelling of the wood cells, changing the size of the cells. Therefore, the lowering or raising of the moisture content causes lumber to shrink or swell.

The loss of moisture during seasoning causes wood to be (1) harder, (2) stronger, (3) stiffer, and (4) lighter in weight. There are two methods for seasoning lumber—air drying and kiln drying.

Air-dried lumber is exactly what the name implies. It is wood placed in a shed or in the open to dry. This method takes up to 7 years to season some woods.

A faster method of drying is known as kiln drying. The wood is placed in a kiln and treated with steam. The time required for drying varies from 2 or 3 days to several weeks. Often a combination of air-dried and kiln-dried methods is used to dry lumber.

Lumber is dry enough for most uses when the moisture content reduces to about 12 or 15 percent. However, lumber used for patterns should be drier. The moisture content should be 8 or 10 percent for hardwoods and 10 to 12 percent for softwoods. As an HT, you will learn to judge the dryness of a wood by its color, weight, smell, and feel. Looking at the shavings and chips also helps identify wood.

LUMBER DEFECTS AND BLEMISHES

A defect in lumber is any flaw that affects the strength, durability, or utility value of the lumber. A blemish is a flaw that mars only the appearance of the lumber. A blemish that affects the utility value of the lumber (such as a blemish in wood intended for fine furniture or cabinet work) is also a defect.

You will seldom find a piece of lumber that does not have a defect or blemish of some sort. Some defects and blemishes are the result of decay in the growing tree. Others are the result of insects,

worms, and fungi, which can cause defects either before or after the lumber is cut. Improper seasoning causes other defects and blemishes.

The most common defects are knots. Knots occur in most kinds of lumber and are the result of branch growth. An interwoven knot forms while the tree is alive. Its annual rings are interwoven with those of the trunk of the tree. Usually an *interwoven knot* is solid and is not a serious defect. If the limb dies before the tree is cut, the wood formed in the trunk of the tree makes no further connection with the limb, but grows around it. This produces a *dead knot.* This may be loose enough to drop out or may be tight enough to hold its shape and position when the tree is being sawed into lumber. A *spike knot* is a long, thin knot caused by the way the tree was sawed. Small, solid knots are not objectionable in most of the lumber used aboard ship. If lumber has loose or large knots, you should cut it into smaller pieces to eliminate these defects.

Heartshake and windshake (fig. 3-5) are other lumber defects. Heartshake is caused by the action of the wind and is a lengthwise separation of the annual rings. Windshake is also a defect caused by the action of the wind, which causes the tree to twist.

A CHECK is a crack or separation, usually short, caused by the uneven shrinking of the wood cells in seasoning. Do not confuse these with pitch pockets. Pitch pockets are small enclosed spaces in the wood filled with sap or pitch (rosin).

WARP or WARPAGE is a lumber defect in which a board distorts from a true, flat surface; it is twisted, bowed, or cupped warped. The varying amount of moisture in the wood changes the diameter of the cells. This causes the board to shrink or swell in width as well as in thickness, but not in length. Redwood is an exception because it will swell or shrink in all three dimensions.
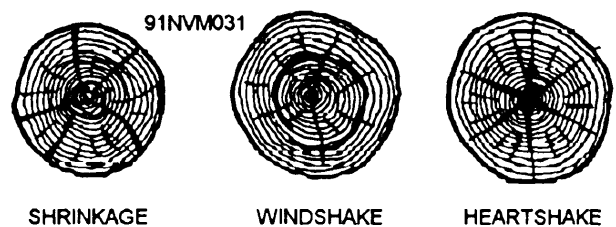
Figure 3-5.—Defects in logs.

WANE is a term that identifies a board that is not full or true to size. It lacks wood along corners, edges, or ends, or is partially composed of bark.

BLUE STAIN is a blemish caused by a mold fungus. It does not weaken the wood.

A BARK POCKET is a patch of bark that has had the tree grow over. It is entirely or almost entirely enclosed.

CROSS-GRAINED LUMBER has grain that is not parallel to the length of the lumber.

There are several lumber defects caused by improper seasoning. One common one is honeycombing. Honeycombing is a series of checks or cracks on the surface or in the center of the lumber caused by drying stresses. If the stress is not relieved by the addition of moisture during the seasoning process, honeycombing will result.

LUMBER SIZES

Lumber is sized according to how thick it is. Boards are pieces of lumber less than 2 inches thick. Planks or dimension lumber are pieces of lumber from 2 to 5 inches thick. Timbers are heavier pieces. Softwoods are usually cut to standard thicknesses, widths, and lengths.

The dressed dimensions of lumber are always smaller than the specified size (nominal size) (table 3-1). The nominal size is the size of the lumber in its rough form as it comes from the saw mill. Dressed lumber has been surfaced (planed smooth) on two or four sides. Lumber surfaced on two sides is S2S (surfaced on two sides). Lumber surfaced on four sides is S4S (surfaced on four sides).

Table 3-1.—Nominal and Dressed Lumber Sizes

Nominal Size	Dressed Dimensions
2×2	$1\ 5/8 \times 1\ 5/8$
2×4	$1\ 5/8 \times 3\ 5/8$
2×6	$1\ 5/8 \times 5\ 5/8$
2×8	$1\ 5/8 \times 7\ 1/2$
2×10	$1\ 5/8 \times 8\ 1/2$
2×12	$1\ 5/8 \times 11\ 1/2$
4×4	$3\ 5/8 \times 3\ 5/8$

All softwood framing lumber, and most other softwood lumber, is cut to even-numbered foot lengths, such as 10 feet, 12 feet, and 14 feet. Hardwood is sometimes cut to odd-numbered as well as even-numbered foot lengths.

Hardwoods used for cabinets, furniture, and other finish work are cut to specific thicknesses (in graduations of 1/4 inch). They are cut to random widths and lengths (RWL) with a specified minimum. For example, a written order for walnut would be 4/4x4x6 RWL. This would tell the supplier that you require material 1 inch thick (4/4), at least 4 inches wide, and at least 6 feet long.

LUMBER GRADES

Lumber grades are based on the type and extent of defects, size of the pieces, and seasoning condition. Softwood lumber is graded for quality according to American Lumber Standards. These standards are set by the National Bureau of Standards for the U.S. Department of Commerce. The major quality grades, in descending order of quality, are select lumber (usually used for interior finish) and common lumber (usually used for house construction). Each grade has subdivisions in descending order of quality as follows:

1. Select lumber

Grade A lumber. This lumber is select lumber that is practically free of defects and blemishes.

Grade B lumber. This is select lumber that contains a few minor blemishes.

Grade C lumber. This is finish item lumber that contains more blemishes and more significant blemishes than grade B. These blemishes must be able to be easily and thoroughly concealed with paint.

Grade D lumber. This is finish item lumber that contains more blemishes and more significant blemishes than grade C, but it is still capable of presenting a satisfactory appearance when painted.

2. Common lumber

No. 1 common lumber. This is sound, tight-knotted stock containing only a few minor

defects. It must be suitable for use as watertight lumber.

No. 2 common lumber. This lumber contains a few significant defects, but no knotholes or other serious defects.

No. 3 common lumber. This lumber contains a few defects that are larger and coarser than those in No. 2 common; for example, occasional knotholes.

No. 4 common lumber. This lumber is low quality and contains serious defects like knotholes, checks, shakes, and decay.

No. 5 common lumber. This lumber is capable only of holding together under ordinary handling.

Mill-run lumber is everything that is sawed except the slabs (bark). Some associations use grades of construction known as standard, utility, and economy.

All species of lumber are covered by the grading rules and size standards of some association or grading bureau. Softwood lumber standards are set by a regional association of manufacturers. In a few cases, a softwood species growing in more than one region is graded under rules of two different associations. It is better to buy according to these association grades than to try to buy according to individualspecifications, unless the requirements are very unusual. Occasionally a departure from the standard grade provision is necessary. This is handled as an exception to a standard grade.

Hardwoods are graded as firsts, seconds, selects, No. 1 common, and No. 2 common. These grades indicate only the amount of clear usable lumber in a particular piece. They are established by the National Hardwood Manufacturers' Association. The way to buy hardwoods for any use other than construction is by personal inspection.

MEASURING LUMBER

When you are measuring lumber, *thickness* is the dimension between the two face surfaces, *Width* is the dimension between the two edges that are parallel to the wood grain. *Length* is the dimension between two ends and is parallel to the wood grain regardless of the width dimension.

It is common practice to state the thickness dimension in inches first; the width in inches second; and the length in feet last. For example, if you were told to get a 2 by 4 by 6, you would know to get a board 2 inches thick by 4 inches wide by 6 feet long.

The standard measure for lumber is a *board foot*. This is abbreviated as bf or bd ft. A board foot is simply one-twelfth of a cubic foot. A board measuring 1 inch thick, 12 inches wide, and 12 inches long contains 1 bd ft. Figure 3-6 shows different size pieces of wood. Each one contains 1 bd ft.

You may use several formulas to determine bd ft. The one most commonly used is the *inches, inches, feet* method. To use it, multiply the thickness (T) in inches by the width (W) in inches by the length (L) in feet. Next, divide the product by 12. Write the formula as follows:

$$bd\ ft = \frac{T(in.) \times W(in.) \times L(ft.)}{12}$$

Suppose you want to determine the bd ft contained in a piece of wood measuring 1 inch thick by 8 inches wide by 9 feet long. Using the formula, you would work it like this:

$$bd\ ft = \frac{T(in.) \times W(in.) \times L(ft.)}{12}$$

$$bd\ ft = \frac{1(in.) \times 8(in.) \times 9(ft.)}{12}$$

$$bd\ ft = 6$$

Therefore, a board measuring 1 inch by 8 inches by 9 feet will contain 6 bd ft.
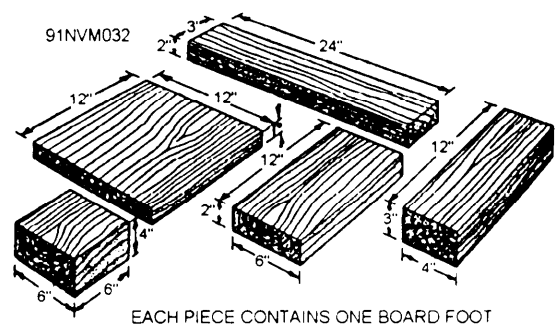
Figure 3-6.—The board foot.

A board less than 1 inch thick is figured as 1 inch when you are calculating bd ft. A board more than 1 inch thick is figured to the next larger 1/4-inch increment. Thus, a board having a thickness of 1 1/8 inches calculates as 1 1/4 inches. Board measure calculates on the basis of the nominal not the dressed dimension of the lumber.

Another common way of measuring lumber is by linear measure. Linear measure is simply the length measurement of a piece of lumber. Therefore, if you had a 2 by 4 by 6, its linear measurement would be 6 feet. This method is often used when buying dimensioned lumber for construction purposes.

COMMON TYPES OF WOODS

Before proceeding with this chapter, review the sources, uses, and characteristics of the various types of common woods provided in table 3-2.

Table 3-2.—Common Woods

TYPE	SOURCES	USES	CHARACTERISTICS
Ash	East of Rockies.	Oars, boat thwarts, benches, gratings, hammer handles, cabinets, ball bats, wagon construction, farm implements.	Strong, heavy, hard, tough, elastic, close straight grain, shrinks very little, takes excellent finish, lasts well.
Balsa	Ecuador.	Rafts, food boxes, linings of refrigerators, life reserves, loud speakers, sound-proofing, air-conditioning devices, model airplane construction.	Lightest of all woods. Very soft, strong for its weight, good heat insulating qualities, odorless.
Basswood	Eastern half of U.S. with exception of coastal regions.	Low-grade furniture, cheaply constructed buildings, interior finish, shelving, drawers, boxes, drainboards, woodenware, novelties, excelsior, general millwork.	Soft, very light, weak, brittle, not durable, shrinks considerably. Interior to poplar, but very uniform, works easily. Takes screws and nails well and does not twist or warp.
Beech	East of Mississippi River, Southeastern Canada.	Cabinetwork, imitation mahogany furniture, wood dowels, capping, boat trim, interior finish, tool handles, turnery, shoe lasts, carving, flooring.	Similar to birch but not so durable when exposed to weather. Shrinks and checks considerably. Close-grained, light or dark red color.
Birch	East of Mississippi River and north of Gulf Coast States, Southeast Canada, Newfoundland.	Cabinetwork, imitation mahogany furniture, wood dowels, capping, boat trim, interior finish, tool handles, turnery, carving.	Hard, durable, fine grain, even texture, heavy, stiff, strong, tough. Takes high polish, works easily. Forms excellent base for white enamel finish, but not durable when exposed. Heartwood is light to dark reddish brown in color.

Table 3-2.—Common Woods—Continued

TYPE	SOURCES	USES	CHARACTERISTICS
Butternut	Southern Canada, Minnesota, Eastern U.S. as far south as Alabama and Florida.	Toys, altars, woodenware, millwork, interior trim, furniture, boats, scientific instruments.	Very much like walnut in color but softer. Not so soft as white pine and basswood. Easy to work, coarse-grained, fairly strong.
Cypress	Maryland to Texas, along Mississippi Valley to Illinois.	Small boat planking, siding, shingles, sash, doors, tanks, silos, railway ties.	Many characteristics similar to white cedar. Water-resistant qualities make it excellent for use as boat planking.
Doulgas fir	Pacific Coast, British Columbia.	Patternmaking, deck planking on large ships, shores, strongbacks, plugs, filling pieces and bulkheads of small boats, building construction, dimension timber, plywood.	Excellent structural lumber. Strong, easy to work, clear straight grained, soft but brittle. Heartwood is durable in contact with ground. Best structural timber of northwest.
Elm	States east of Colorado.	Agricultural implements, wheel-stock, boats, furniture, crossties, posts, poles.	Slippery, heavy, hard, tough. Durable, difficult to split, not resistant to decay.
Hickory	Arkansas, Tennessee, Ohio, Kentucky.	Tools, handles, wagon stock, hoops, baskets, vehicles, wagon spokes.	Very heavy, hard, stronger and tougher than other native wood, but checks and shrinks. Difficult to work. Subject to decay and insect attack.
Lignum vitae	Central America.	Patternmaking, block sheaves, and pulleys, water-exposed shaft bearings of small boats and ships, tool handles, small turned articles, and mallet heads.	Dark greenish brown. Unusually hard, close-grained, very heavy, resinous. Difficult to split and work, has soapy feeling.
Live oak	Southern Atlantic and Gulf Coasts of U.S., Oregon, California.	Implements, wagons, shipbuilding.	Very heavy, hard, tough, strong, durable. Difficult to work. Light brown or yellow sap wood nearly white.
Mahogany	Honduras, Mexico, Central America, Florida, West Indies, Central Africa, other tropical sections.	Patternmaking, furniture, boats, decks, fixtures, interior trim in expensive homes, musical instruments.	Brown to red color. One of most useful of cabinet woods, hard, durable. Does not split badly. Open-grained, takes beautiful finish when grain is filled but checks, swells, shrinks, warps slightly.

Table 3-2.—Common Woods—Continued

TYPE	SOURCES	USES	CHARACTERISTICS
Maple	All states east of Colorado, Southern Canada.	Patternmaking, excellent furniture, high-grade floors, tool handles, ship construction crossties, counter tops, bowling pins.	Fine-grained, grain often curly or "bird's eyes." Heavy, tough, hard, strong. Rather easy to work, but not durable. Heartwood is light brown, sap wood is nearly white.
Norway pine	States bordering Great Lakes.	Dimension timber, masts, spars, piling, interior trim.	Light, fairly hard, strong. Not durable in contact with ground.
Philippine mahogany	Philippine Islands	Patternmaking, pleasure boats, medium-grade furntiure, interior trim.	Not a true mahogany. Shrinks, expands, splits, warps, but available in long, wide, clear boards.
Poplar	Virginias, Tennessee, Kentucky, Mississippi Valley.	Patternmaking, low-grade furniture, cheaply constructed buildings, interior finish, shelving, drawers, boxes.	Soft, cheap obtainable in wide boards. Warps, shrinks, rots easily. Light, brittle, weak, but works easily and hold nails well, fine-textured.
Red cedar	East of Colorado and north of Florida.	Mothproof chests, lining for linen closets, sills, and other uses similar to white cedar.	Very light, soft, weak, brittle, low shrinkage. Great durability, fragrant scent. Generally knotty, beautiful when finished in natural color. Easily worked.
Red oak	Virginias, Tennessee, Arkansas, Kentucky, Ohio, Missouri, Maryland.	Interior finish, furniture, cabinets, millwork, crossties when preserved.	Tends to warp. Coarse-grained. Does not last well when exposed to weather. Porous easily impregnated with preservative. Heavy, tough, strong.
Redwood	California.	Patternmaking, general construction, tanks, paneling.	Inferior to yellow pine and fir in strength. Shrinks and splits little. Extremely soft, light straight-grained. Very durable, exceptionally decay resistant.
Spruce	New York, New England, West Virginia, Central Canada, Great Lakes states, Idaho, Washington, Oregon.	Railway ties, resonance wood, piles, airplanes, oars, masts, spars, baskets.	Light, soft, low strength, fair durability, close grained, yellowish, sap wood indistinct.
Sugar pine	California, Oregon.	Same as white pine.	Very light, soft, resembles white pine.
Teak	India, Burma, Java, Thailand.	Deck planking, shaft logs for small boats.	Light brown color. Strong, easily worked, durable, resistant to damage by moisture.

Table 3-2.—Common Woods—Continued

TYPE	SOURCES	USES	CHARACTERISTICS
Walnut	Eastern half of U.S. except Southern Atlantic and Gulf Coasts, some in New Mexico, Arizona, California.	Expensive furniture, cabinets, interior woodwork, gun stocks, tool handles, airplane propellers, fine boats, musical instruments.	Fine cabinet wood. Coarse-grained but takes beautiful finish when pore closed with wood filler. Medium weight, hard, strong. Easily worked. Dark chocolate color. Does not warp or check, brittle.
White cedar	Eastern Coast of U.S. and around Great Lakes.	Boat planking, railroad ties, shingles, siding posts, poles.	Soft, light weight, close-grained. Exceptionally durable when exposed to water. Not strong enough for building construction. Brittle, low shrinkage, generally knotty.
White oak	Virginias, Tennessee, Arkansas, Kentucky, Ohio, Missouri, Maryland, Indiana.	Boat and ship stems, sternposts, knees, sheer strakes, fenders, capping, transoms, shaft logs, framing for buildings, strong furniture, tool handles, crossties, agricultural implements, fence posts.	Heavy, hard, strong. Medium coarse-grained. Tough, dense, most durable of hardwoods. Elastic, rather easy to work, but shrinks and likely to check. Light brownish grey in color with reddish tines. Medullary rays are large and outstanding and present beautiful figures when quarter sawed. Receives high polish.
White pine	Minnesota, Wisconsin, Maine, Michigan, Idaho, Montana, Washington, Oregon, California.	Patterns, any interior job or exterior job that doesn't require strength, window sash, interior trim, millwork, cabinets, cornices.	Easy to work. Fine-grained, free of knots. Takes excellent finish. Durable when exposed to water, expands when wet, shrinks when dry. Soft, white. Nails without splitting, not very strong, straight-grained.
Yellow pine	Virginia to Texas.	Most important lumber for heavy construction and exterior work, keelsons, risings, filling pieces, clamps, floors, bulkheads of small boats, shores, wedges, plugs, strongbacks, staging, joists, posts, piling, ties, paving blocks.	Hard, strong, heartwood is durable in the ground. Grain varies. Heavy, tough, reddish brown in color. resinous, medullary rays well marked.

LUMBER

Woods that have a comparatively straight, close grain, that are easy to work, and that do not warp or shrink easily are the woods you should select for pattern work. Do not select boards containing too much moisture or pitch. Such boards are difficult to work with, shrink excessively, and will not keep a smooth surface.

A board that contains excess pitch may be unusually heavy. When planed, large amounts of

pitch may be seen. Excessive moisture cannot always be detected by weight. Detection comes when the board is crosscut or dressed.

Kinds of Lumber

The woods most frequently used in the carpenter shop for most projects are redwood, white pine, ponderosa pine, mahogany, and poplar.

REDWOOD is inferior to the better grades of sugar pine and white pine, but for most patterns it works well. The best grades work easily. Redwood has one peculiar property that no other wood has—it shrinks in length as well as in thickness and in width. The name redwood derives from the reddish-brown color of the wood itself. It is related to pine but is much more durable when in contact with soil or when exposed to weather.

The redwood tree grows exclusively on the West Coast. The age of these forest giants runs as high as 3,000 to 4,000 years. They frequently grow to a height of 350 feet, with a diameter of 25 feet or greater.

WHITE PINE is the best wood for making simple patterns that are used less than 30 times and that are under 2 feet in length. This softwood is smooth, straight and even-grained, light, and warps very little when properly seasoned. White pine that is free from knots is the cheapest of lumber. With sharp tools, you can cut and carve white pine almost like soap. White pine takes a good coat of lacquer or glue, but it chips or breaks easily. Its color ranges from almost white to light yellowish-brown.

In the West, the name *white pine* usually applies to the native sugar pine that grows in northern California and southern Oregon.

PONDEROSA PINE is sometimes mistakenly called sugar pine. It closely resembles the sugar pine, but it is not good for some types of work such as pattern work. It warps and shrinks a lot and has more pitch than sugar pines.

MAHOGANY is more durable and harder than pine. Use it when 30 to 100 castings are required. Also, use it for patterns having long or thin sections or projections. Mahogany is strong, coarse-grained, and warps very little. It is soft enough to cut and nail easily, yet hard enough to stand a lot of wear. Mahogany is difficult to plane or carve in the direction of the grain, but it is excellent for cross-grain carving. Mahogany will outlast pine 3 to 1.

Several varieties of mahogany are used. Spanish mahogany is from the West Indies, Honduras mahogany (also called baywood) and Mexican mahogany is from Central America and Mexico, and Senegal mahogany is from Africa. Distinguishing between varieties is difficult. Mahogany is usually reddish-brown, but it often varies in color.

POPLAR is used in many carpenter and pattern shops. It is soft with close, straight grain. Its use is limited because of brittleness and excessive warping and shrinkage. Poplar ranges in color from off-white to light yellow. The poplar tree grows in the eastern part of the United States. It goes from the Gulf of Mexico north into southern Canada.

Other woods used by HTs are discussed in the following paragraphs.

MAPLE, especially eastern maple, is very hard and is difficult to work. It varies in color from light brown to white. Oregon maple (western soft maple) is close-grained and reddish-brown in color. This wood is mostly used in the manufacture of furniture and tool handles. Oregon maple is also used for certain projects that must endure heavy wear or that are weak because of their shape or size. Maple will outlast pine 8 to 1.

WHITE ASH is open-grained, elastic, and hard. The color of the heartwood is light brown. The sapwood is almost white.

BLACK WALNUT grows in the eastern part of the United States. It is very durable and very hard. When used as pattern material, black walnut will outlast pine 5 to 1.

HICKORY is the strongest, heaviest, and toughest of all American woods. It is also flexible. The color of hickory varies from brown to white.

OREGON PINE (Douglas fir) is of two varieties, red and yellow. The yellow is the more valuable of the two, being hard, strong, and very durable—but difficult to work.

CHERRY is brown in color, close-grained, and very hard—but warps excessively. Cherry is a little

difficult to carve, but when used for small patterns, it will outlast pine 5 to 1.

LIGNUM VITAE is excessively heavy, hard, and resinous. Its color varies from light yellow to dark greenish-brown—at times almost black. This wood is native to tropical America, New South Wales, and New Zealand.

TEAK is heavy, strong, and oily. It has a dark color. It does not shrink, crack, or warp. Teak comes from East India.

Care and Storage of Lumber

Lumber is a tool like the saw or plane and should be considered as such. Store and care for lumber properly. This will prevent it from becoming water-soaked, rotted, or warped. The best way to stow lumber is by stacking it on end in racks. This way air can circulate around all the boards. Circulation dries the wood evenly and reduces warping.

Room for storing lumber on end is hard to find aboard ship. Lumber usually gets stored in the next best manner. The accepted method is to store the lumber horizontally. Separate the lumber by sizes. Put the l-inch lumber together, the 1 1/2-inch lumber together, and so on. When placing the lumber in racks, you should place small strips or battens about 1 inch thick across the boards about 6 feet apart. This will separate the boards and form a space for the air to circulate around them. Air circulation is important. A dressed board laid on its flat surface without full air circulation will usually warp toward the exposed surface. The air draws more moisture from the exposed surface than from the underneath surface.

The carpenter shop usually has overhead lumber storage racks. The bulk of the lumber is stowed in other parts of the ship because of space limitations aboard a repair ship or tender.

You should maintain a careful record of the lumber used and on hand. If possible, at least 3 months' supply should be on hand.

MANUFACTURED WOOD PRODUCTS

Laminated lumber is made up of layers of wood glued face-to-face (fig. 3-7). The parts glued together to make laminated lumber may be thinly sliced sheets of veneer or they may be sawed boards.

One advantage of laminated wood is that it can be any desired thickness. Also, staggering the ends of individual layers can produce timbers that are much longer than solid timbers.

Plywood (fig. 3-8) is thin layers of wood glued face-to-face. It usually has the grain of each layer at right angles to the next layer. Plywood alternates grain each ply, and laminated wood never alternates grain. Plywood always has an odd number of plies. Veneered stock for furniture manufacture usually has five layers. A thick layer called the core is in the center. The layers that are glued on with the grain running across are called cross bands. The surface layers or faces are placed so their grain runs parallel to the length of the panel.

One-quarter inch and one-eighth inch fir plywood has only 3 plies. Plywood always has an odd number of plies—up to 15. The standard size of

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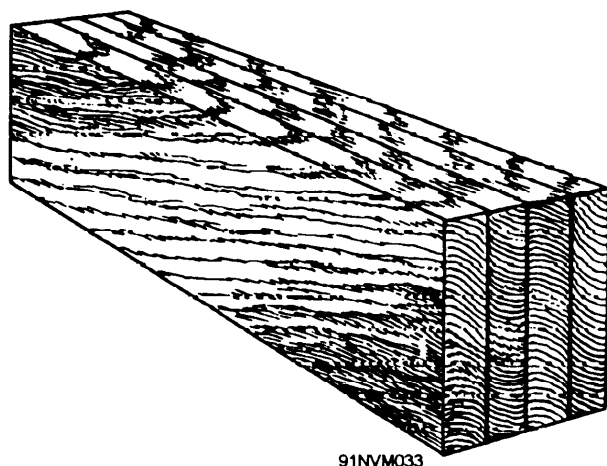
Figure 3-7.—Laminated lumber.

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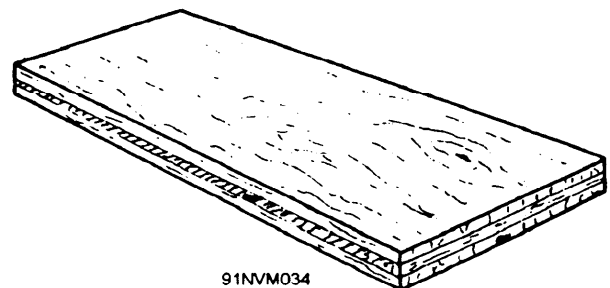
Figure 3-8.—Plywood.

plywood sheets is 4 feet wide by 8 feet long, though smaller and larger sizes are available. Because of the cross-grain effect, splitting plywood is very difficult and shrinking and swelling are rare.

The development of special glues and bonding materials has made plywood highly resistant to water. It was widely used during World War II and is still in use in the Navy.

Two basic grades of plywood are interior and exterior. Interior plywood is unreliable in wet places. Exterior plywood will keep its original form and strength when subjected to the elements. It is suitable for permanent exterior use provided it is properly protected from the elements. Most plywood is branded or stamped on the edge with the symbol EXT. or INT. More complete information is stamped on the back of the plywood sheet. A typical Douglas fir back stamp, with all symbols explained, is shown in figure 3-9.

Plywood is graded by the quality of the face veneers. Grade A is the best. Grade D is the poorest (fig. 3-9). Grading is based upon the number of defects, such as knotholes, pitch pockets, and splits. It also considers the presence of streaks, discolorations, sapwood, shims, and patches in the face of the panel. Plywood has resin-impregnated fiber faces that provide better painting surfaces and better wearing qualities.

Because of the conditions of its manufacture, plywood is dry when received. It should be stored in a closed shed. For long storage, a heated storage area is recommended.

Plywood is commonly stacked in solid piles. Under humid conditions, edges swell because of exposed end grain. This swelling causes dishing, especially in the upper panels of high piles. Reduce dishing by placing strips between sheets of stacked plywood. Use enough strips to prevent the plywood from sagging between strips. Dry l-inch strips are suitable for supporting plywood.

Hardboard is known by several trade names. It is wood fibers separated, treated, and then subjected to heat and heavy pressure. Hardboard is available in thicknesses from 1/16 inch to 5/6 inch. The most common size is 4-foot by 8-foot sheets, but other sizes are available. Hardboard comes in a plain, smooth surface or in several glossy finishes. Some finishes imitate tile or stone. Use class B treated hardboard where moisture resistance or strength is required. Otherwise, class A hardboard is satisfactory.
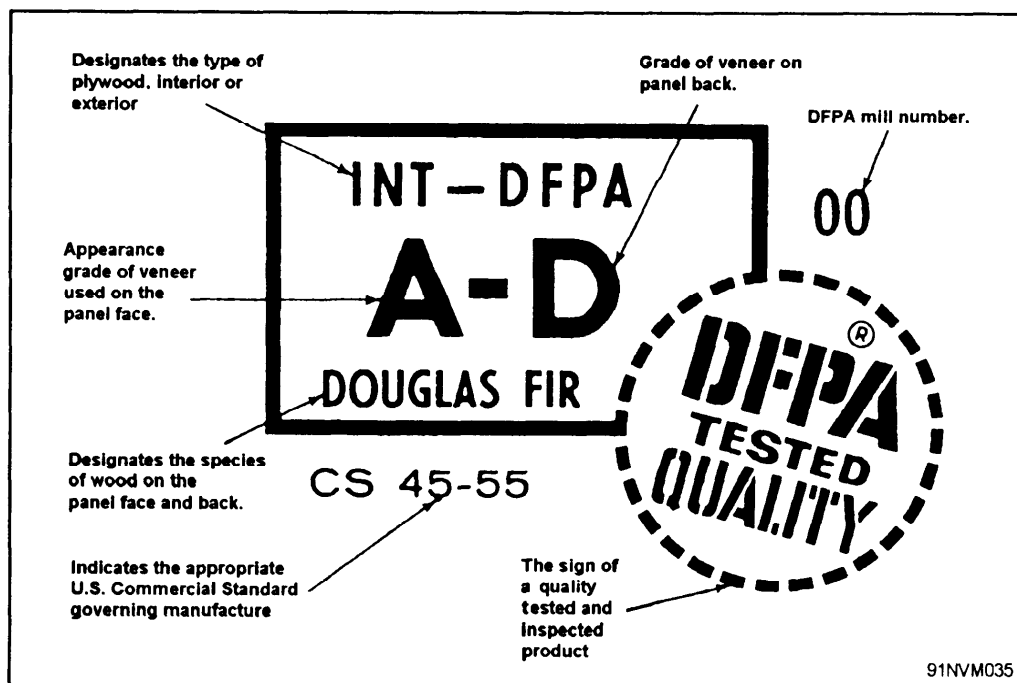
Figure 3-9.—Typical Douglas fir back stamp.

WOOD JOINERY

An important skill to master is wood joinery. In woodworking, joinery is the art of combining two or more pieces of material into one. The purpose for this procedure is to increase dimensions, strength, or material alignment. Wood joinery includes the manufacture of wood joints and the various devices or methods used to fasten them together. These methods include glue, screws, and brads.

A joint is only as strong as its weakest point. This can be the joints if they are incorrectly made or if you use the wrong joint. Correct joint usage and proper construction can make the joint the strongest point of the project.

STANDARD JOINTS

There are four standard methods for joining wood stock edge-to-edge. These methods are the plain butt, dowel, tongue-and-groove, and splined edge joints shown in figure 3-10.

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PLAIN BUTT

90° PLAIN BUTT

DOWELED   TONGUE & GROOVE   SPLINE
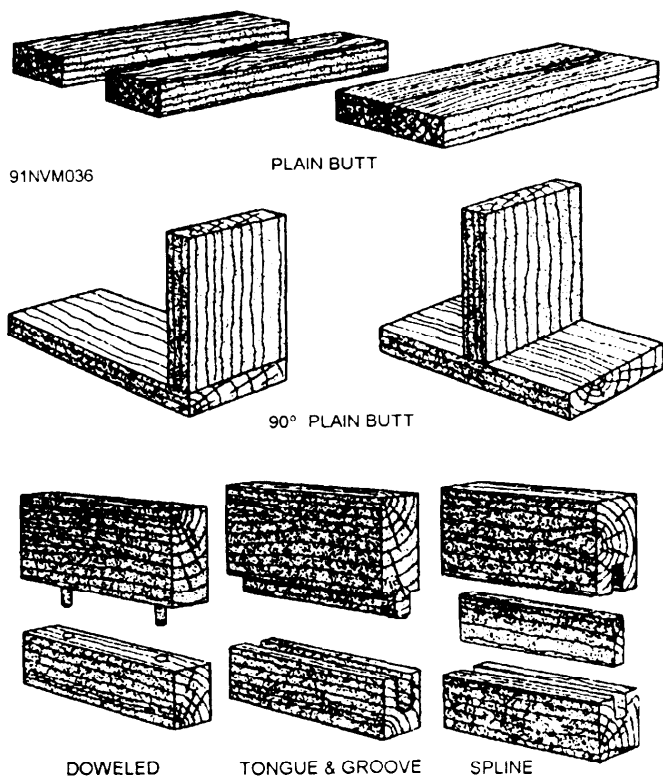
Figure 3-10.—Edge joints.

The plain butt joint is the simplest and the one most used by the HT.

The doweled joint is usually a plain butt joint that has been given greater strength with wooden dowels. Dowels also reinforce other joints such as the miter and half lap.

When choosing a dowel for edge-to-edge use, the dowel diameter should be one-third the thickness of the stock you are jointing. Thus, 3/4-inch thick stock would require a 1/4-inch dowel.

The tongue-and-groove joint is stronger than the butt or dowel joint. It is used for wood flooring.

The splined edge joint is a variation of the tongue-and-groove joint. It is easier to make because two matching grooves and a separate spline replace the tongue. Minimal strength is gained if the grain direction of the spline is parallel to the edges, as shown in figure 3-11. A significant strength gain results when the grain direction of the spline is perpendicular to the edges.

The thickness of both the spline and tongue should be one-third of the material thickness. The width of the spline should be equal to twice the material thickness, while the tongue width should be the same as the thickness. For example, 3/4-inch stock would require a spline measuring 1/4 inch thick and 1 1/2 inches wide or a tongue measuring 1/4 inch thick and 3/4 inch wide (fig. 3-11).

Lap Joints

Lap joints are shown in figure 3-12. Plain lap joints are used in all kinds of construction, particularly if appearance is not a factor. The end butt half lap is not as strong as the plain lap joint, but it looks better and requires less space. The corner half lap works well for framing buildings, boxes, and cabinets. The cross lap joint joins the spokes of a wheel pattern.

The scarf joint (fig. 3-13) is a special type of lap joint that is used to join heavy timbers. For repair purposes, the recommended slope is 1 in 12. The cut should slant through the length of a piece of wood 12 inches for every inch of depth or width.

The end butt joint with fishplates (fig. 3-14) is useful for joining short members to make long pieces. Secure the fishplates with nails, screws,
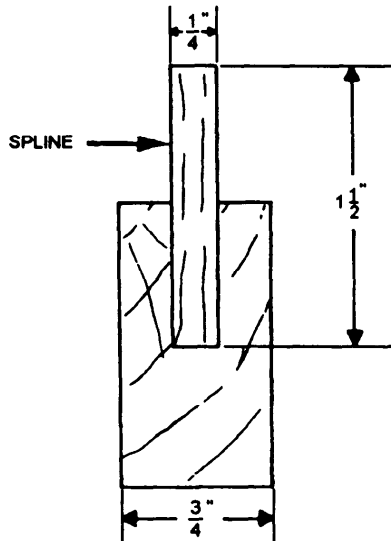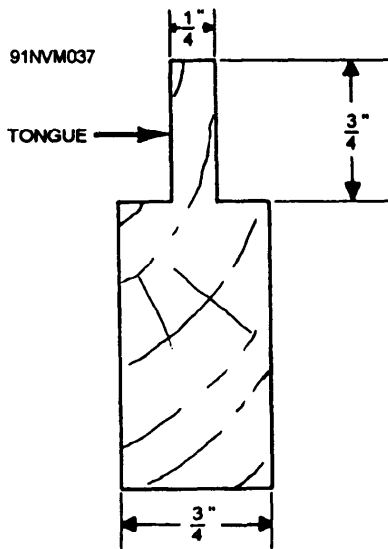
Figure 3-11.—Tongue and spline joints.

Figure 3-12.—Lap joints.

The gain joint (fig. 3-15) is a special kind of dado joint. You use it when appearance is a factor.

Rabbet joints are often used with dadoes. They are cut across or with the grain (fig. 3-16). Cut rabbets with the circular saw dado head or with the jointer. They can be cut by hand using special rabbeting planes.

Dovetail Joints

Cabinetmakers and other skilled woodworkers often use the dovetail joint (fig. 3-17). It is used most often in joining the corners of furniture drawers and chests because of its locking features. Such joints are usually made with blind dovetails so

rivets, or bolts. Its main disadvantage is that it is bulky.

Dado, Gain, and Rabbet Joints

You would use the plain dado joint (fig. 3-15) to make cabinets and shelves. You would usually cut this joint with a dado head (cutters), which fits on a circular saw. You also can make this cut by hand using a backsaw or tenon saw and finish it with chisels. Fasten this joint with glue, nails, or screws.

Figure 3-13.—Typical scarf joints.

3-15
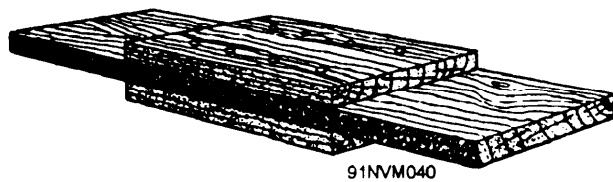
Figure 3-14.—End butt joint with fishplates.

they cannot be seen from the outside of the furniture.

Heavier construction that requires locking joints call for single dovetails and half dovetails. The single dovetail (dovetail key) is a good joint for attaching a loose piece to a pattern. Dove tails require accurate layout. Use a sharp knife edge to mark the layout, not a pencil. Use a T-bevel to lay out the angles. You can use the tenon saw to saw out most of the waste and then finish the work with a chisel.

Box Corner and Miter Joints

Many commercial packing boxes are made with the box corner joint (fig. 3-18). It cuts easily on the circular saw with special dado heads.

The miter joint (fig. 3-19) is used for picture frames, boxes, panel frames, and other frames. Glue the joints, and then fasten miter joints with nails, brads, and corrugated fasteners.

The spline miter is better than the plain miter. Cut it with the table saw and jig. Other miters require more work and are used only on special jobs.

Coping Joints

When matching inside corner joints between molding trim members, use the coping joint (fig.
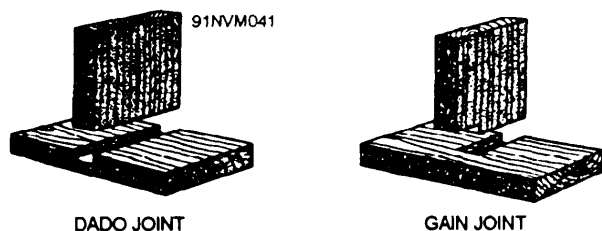
Figure 3-15.—Dado and gain joints.
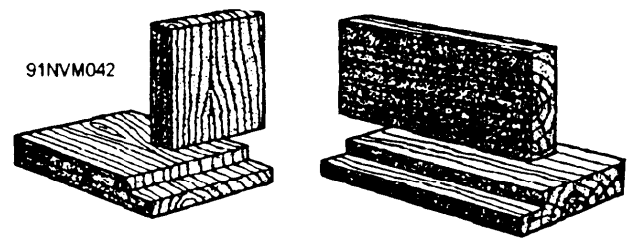
Figure 3-16.—Rabbet joints.

3-20) to shape the end of the abutting member to fit the face of the first member.

Mortise-and-Tenon Joints

Good furniture has several mortise-and-tenon joints (fig. 3-21). This joint appears weak, but when glued it is very strong. It can be wedged, split, or offset. You can't go wrong with properly designed and fitted mortise-and-tenon joints. Use the slip-tenon joint the same way as a miter or corner half-lap joint. Secure it with dowels, screws, bolts, or nails and then glue it.

LAYING OUT AND CUTTING JOINTS

One of the basic skills you must learn in woodworking is to join pieces of wood to form tight, strong joints. The two joined pieces are members. The two major steps in joining members are layout and cutting. Lay out the joints on the ends, edges, or faces of the members. Then cut the members to the required shapes for joining.
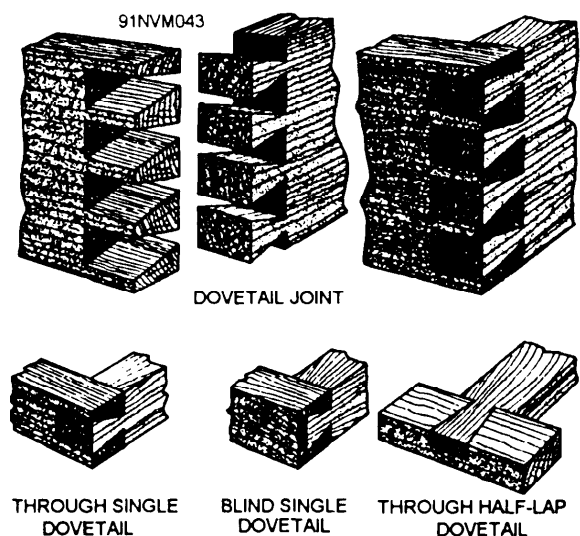
Figure 3-17.—Dovetail joints.
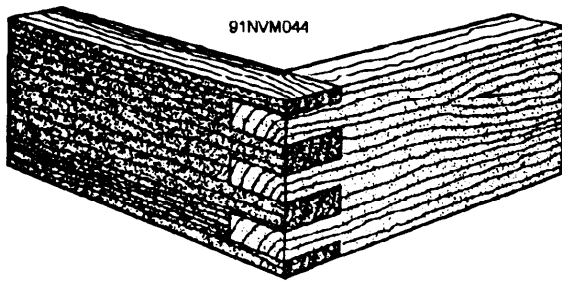
Figure 3-18.—Box corner joint.

Cutting accurate joints requires square and true stock. To square and true stock, you use a jointer for trueing the edges and a surface planer to get uniform thickness. Use a table or radial saw for squaring the ends and cutting stock to the desired length. Often, you will have to perform these operations by hand. Therefore, planing and squaring a small board to dimensions by hand should be the first lesson in woodworking. The six major steps in the process are shown in figure 3-22. Practice them until you learn to make a smooth, square board with minimum planing.

Instruments used for laying out joints are the combination square, the T-bevel, the marking gauge, and a bench knife for scoring lines. For hand cutting joints, use the backsaw, dovetail saw, coping saw, and various chisels and planes.

You can cut all joints mentioned in this chapter by hand or machine. Whatever the method you use and whatever the type of joint, always remember the following rule: To ensure a tight joint, always cut on the waste side of the line, never on the line itself. Cutting a groove on the waste side of the line with a knife or chisel will help a backsaw get a smooth start.

PLAIN MITER JOINT

MITER WITH SPLINE
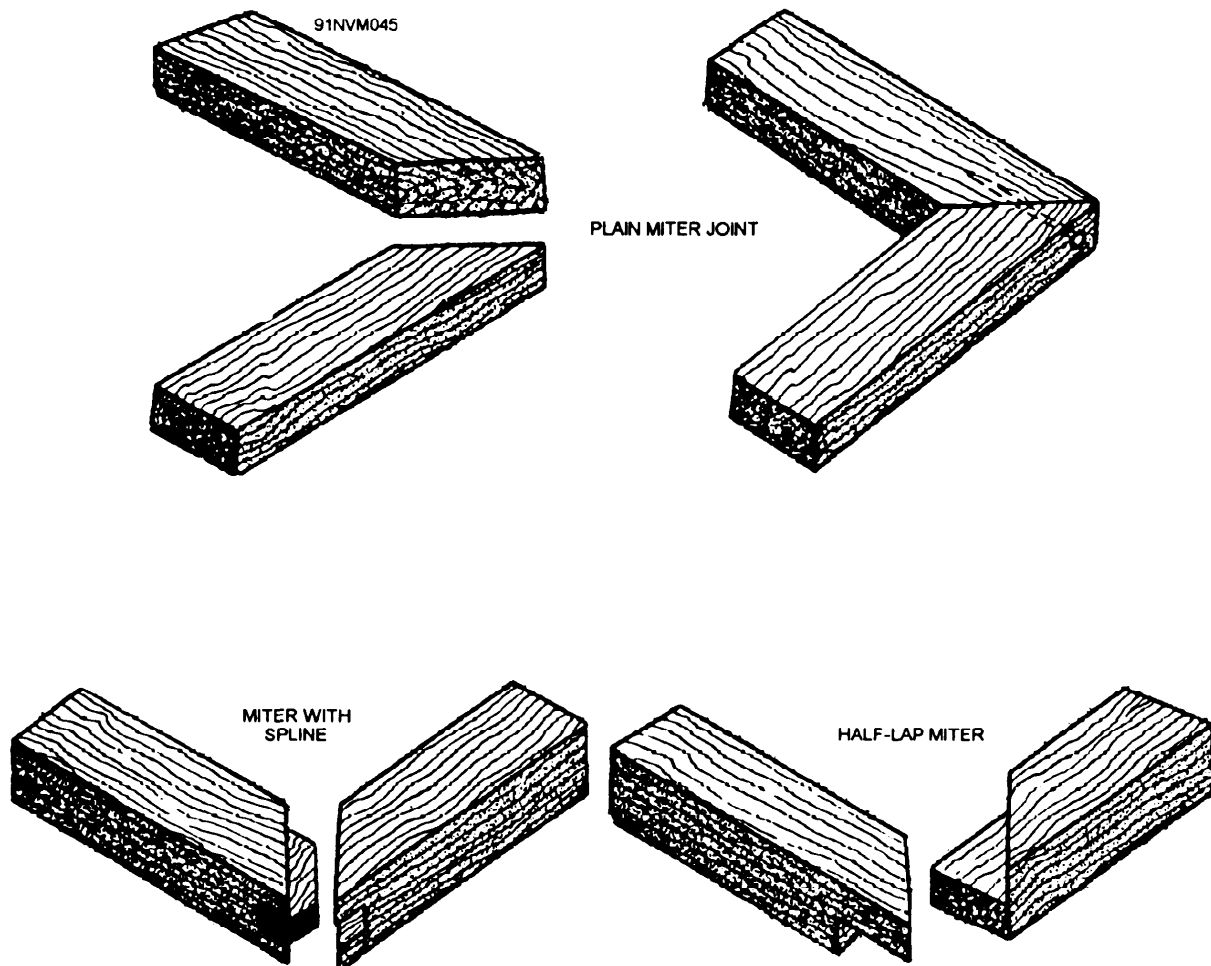
HALF-LAP MITER

Figure 3-19.—Miter joints.

3-17
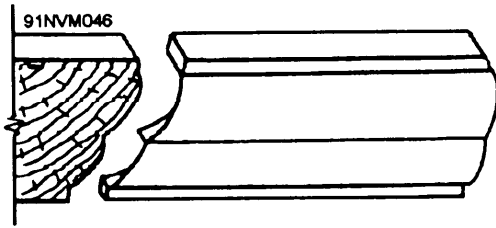
Figure 3-20.—A coping joint.

Half-Lap Joints

For half-lap joints (fig. 3-23), the joining members are usually the same thickness. For the end butt half lap, measure off the desired amount of lap from the end of each member. At this point, use a combination square to guide and to score a line all the way around the member. This is squaring a line. For the corner half lap, measure off the width of a member from the end of each member. Square a line all the way around. These are shoulder lines.

Next, you should select the best surface of each member and place it facing up. This is the face of the member. The opposite surface is the back. Mark the face of each member plainly. Next, set the marking gauge to one-half the thickness of the member. Score a line (called the cheek line) on the

edges and end of each member. This line will extend from the shoulder line on one edge to the shoulder line on the opposite edge (fig. 3-23). Be sure to gauge the cheek line from the face of each member. If you gauge from both faces, the faces will be flush after cutting the joint. The faces must be flush regardless of whether or not the gauge was set to exactly one-half the thickness. Too much waste cut from one member offsets a lesser cut from the other.

If you gauge from the face of one member and the back of the other, and the gauge is not set to one-half the thickness, the faces will be out of flush by the amount of the error. A rule you should use for half-lap joints is to *always gauge the cheek line from the face of the member.*

Next, make the shoulder cuts by sawing along the shoulder line down to the cheek line. Saw from the back of the lapping member and from the face of the lapped member (fig. 3-23). Clamp a piece of wood along the starting groove to steady the saw.

The cheek cuts (sometimes called the side cuts) are next. Cut them along the waste side of the cheek line. Clamp the member in the vise so it leans diagonally away from you. With the member in this position, you can see the end and the upper edge. When the saw reaches the shoulder line on
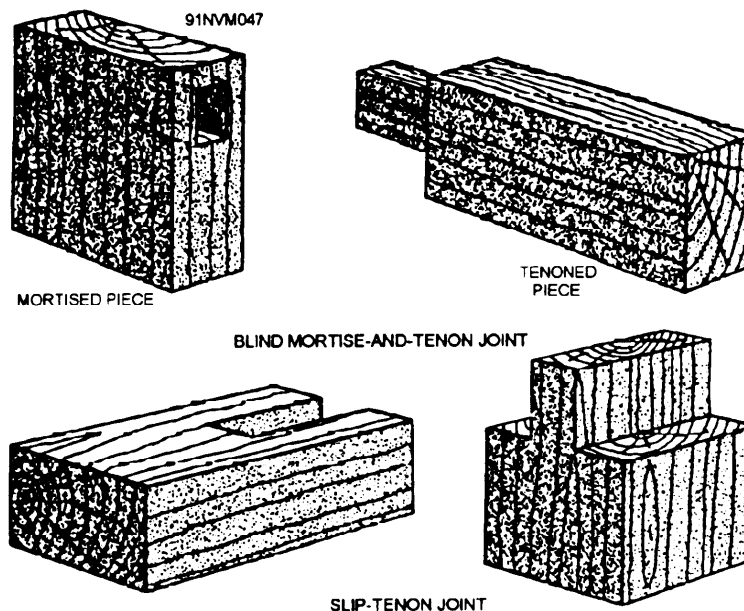
Figure 3-21.—Mortise-and-tongue and slip-tenon joints.

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1. WORK FACE

PLANE ONE BROAD SURFACE SMOOTH AND STRAIGHT. TEST IT CROSSWISE, LENGTHWISE, AND FROM CORNER TO CORNER. MARK THE FACE X.

4. WORK END

MEASURE LENGTH AND SCRIBE AROUND THE STOCK A LINE SQUARE TO THE WORK EDGE AND WORK FACE. SAW OFF EXCESS STOCK NEAR THE LINE AND PLANE SMOOTH TO THE TO THE SCRIBED LINE. TEST THE SECOND END FROM BOTH THE WORK FACE AND THE WORK EDGE.

2. WORK EDGE

PLANE ONE EDGE SMOOTH, STRAIGHT, AND SQUARE TO THE WORK FACE. TEST IT FROM THE WORK FACE. MARK THE WORK EDGE X.

5. SECOND EDGE

FROM THE WORK EDGE GAUGE A LINE FOR WIDTH ON BOTH FACES. PLANE SMOOTH, STRAIGHT, SQUARE, AND TO THE GAUGE LINE. TEST THE SECOND EDGE FROM THE WORK FACE.

3. WORK END

PLANE ONE END SMOOTH AND SQUARE. TEST IT FROM THE WORK FACE AND WORK EDGE. MARK THE WORK END X.

6. SECOND FACE

FROM THE WORK FACE GAUGE A LINE FOR THICKNESS AROUND THE STOCK. PLANE THE STOCK TO THE GAUGE LINE. TEST THE SECOND FACE AS THE WORK FACE IS TESTED.

Figure 3-22.—Planing and squaring to dimension.

the upper edge, it will still be some distance away from the shoulder line on the edge you can't see. Reverse the member in the vise, and saw exactly to the shoulder line on that edge.

Completing the shoulder cut will detach the waste. The members should fit together with faces, ends, and edges flush, or near enough to make flush by a little paring with the chisel.

FACE   WASTE STOCK

CHEEK LINES

BACK   SHOULDER LINES

LAPPED MEMBER

FACE   WASTE STOCK

CHEEK LINES

91NVM049   BACK   SHOULDER LINES

LAPPING MEMBER
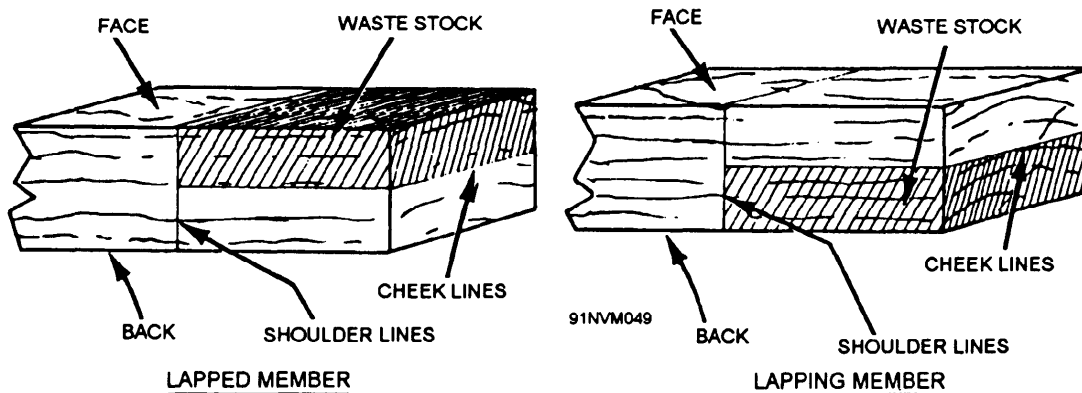
Figure 3-23.—End butt half-lap or comer half-lap joint.

3-19

A cross half-lap joint (fig. 3-24) between members of equal cross-section dimensions is laid out and cut as follows: If the members are of the same length and they are to lap each other at the midpoint, place them face-to-face with ends flush. Then square a center line all the way around. To test the accuracy of the center calculation, turn one of the members end for end. If the center lines still meet, the center location is correct.

When making a cross half-lap joint, you should put the best wide surfaces up and mark each face plainly. Lay off one-half the width of a member on either side of the center lines; then, square the shoulder lines all the way around. Again check for accuracy by turning a member end for end. If the shoulder lines meet, the layout is accurate. Next, gauge one-half the thickness of a member. Do this from the face of each member and score check lines on the edges between the shoulder lines. Next, make the shoulder cuts, sawing from the back of the lapping member and from the face of the lapped member.

In the cross half-lap joint, you should chisel the waste out rather than saw it out. To make the chiseling easier, remove as much stock as possible with the saw first. Saw a series of kerfs between the shoulder cuts. In chiseling, make a roughing cut down to just above the cheek line with a firmer chisel and mallet. Hold the chisel bevel down. Finish off the bottom with a paring chisel while holding the chisel bevel up.

You can use a circular saw to cut half-lap recesses and cross half-lap recesses. For an end half-lap recess, set the table saw blade above the table a distance equal to one-half the thickness of a member. Place the member against the miter gauge, set it at 90° to the saw blade, and make the shoulder cut. Take out the remaining waste by making as many recuts as necessary.

For a cross half-lap recess, you should proceed as follows: Set the table saw blade or dado head so its height above the table is equal to one-half the thickness of a member. Then, place the member against the miter gauge set at 90° to the saw blade
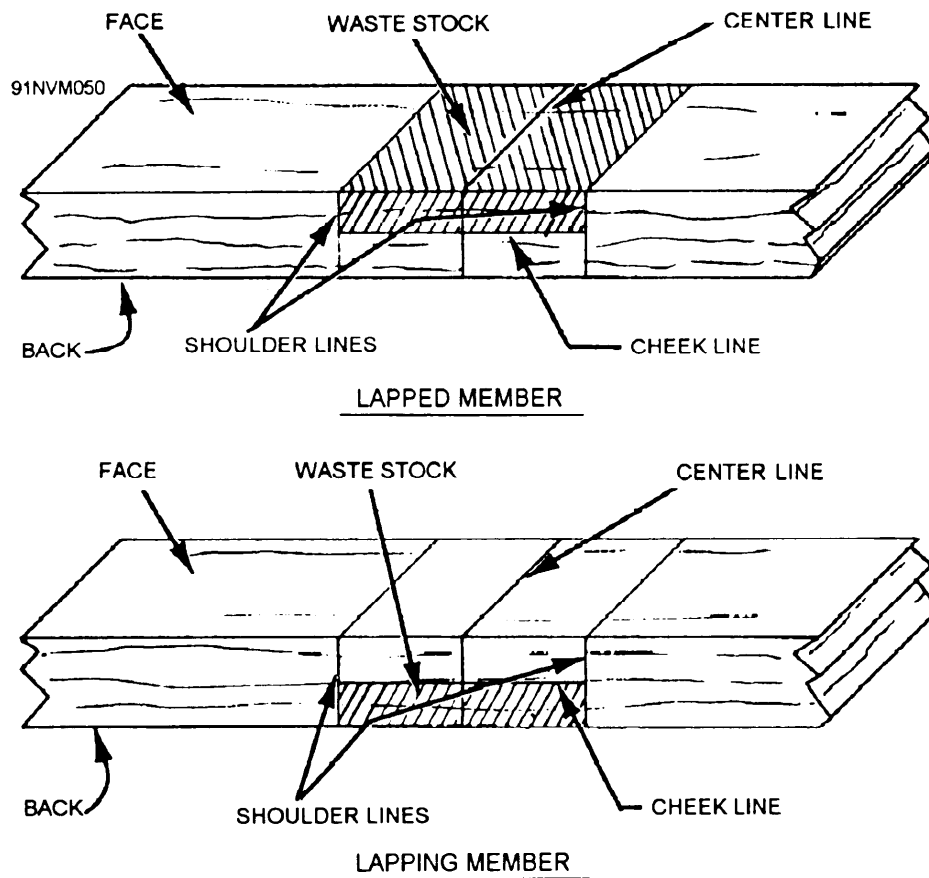
Figure 3-24.—Gross half-lap joint.

and make the shoulder cut. Then, reverse the piece end for end and repeat the procedure to make the opposite shoulder cut. Take out the remaining waste between the shoulder cuts by making as many recuts as necessary.

Grooved Joints

A groove is a three-sided recess running with the grain. A similar recess running across the grain is a dado. A groove or dado that does not extend all the way across the piece is a stopped groove or a stopped dado. A stopped dado is also known as a gain (refer to fig. 3-15).

A two-sided recess running along an edge is a rabbet (refer to fig. 3-16). Dadoes, gains, and rabbets are not actually grooves, but the joints are called grooved joints.

Grooves on edges and grooves on faces of narrow stock can be cut by hand with the plow plane. The matching plane will cut a groove on the edge of one piece. It also cuts a tongue to match it on the edge of another. You can cut a dado by hand with the backsaw and chisel. Use the same method used to cut a cross half-lap joint by hand. Saw rabbets on short ends or edges by hand with the backsaw.

Cut a long rabbet by hand with the rabbet-and-fillister plane by using the following procedure: First, be sure that the side of the plane iron is exactly in line with the machined side of the plane. Then, set the width and depth gauges to the desired width and depth of the rabbet.

NOTE: Be sure to measure the depth from the edge of the plane iron, not from the sole of the plane. If you measure from the sole of the plane, the rabbet will be too deep by the amount that the edge of the iron extends below the sole of the plane.

Next, clamp the piece in the vise. Hold the plane perpendicular, press the width gauge against the face of the board, and plane down with even, careful strokes. Continue until the depth gauge prevents any further planing.

Cut a groove or dado on the circular saw as follows: Lay out the groove on the end of the wood. For a dado, lay out the edge. Set the saw to the depth of the groove above the table. Set the fence so the saw will cause the first cut to run on the waste side of the line. Start the saw and bring the piece into light contact with it. Then stop the saw. Look at the stock to make sure the cut will be on the waste side of the line. Adjust the fence if necessary.

When the fence position is exact, make the cut. Reverse the piece and proceed to set and test as before for the cut on the opposite side of the groove. Make as many cuts as necessary to remove the waste stock between the side kerfs.

Grooving with the dado head is the same as dadoing, with one exception. The dado head builds up to take out all or most of the waste in a single cut. The two outside cutters alone will cut a groove 1/4 inch wide. Inside cutters vary in thickness from 1/16 to 1/4 inch.

The circular saw can cut a stopped groove or stopped dado. You can use either a saw blade or a dado head as follows: Clamp a stop block to the rear of the table if the groove or dado stops at only one end. (This will stop the piece from feeding when the saw has reached the place where the groove or dado is supposed to stop.) If the groove or dado stops at both ends, clamp a stop block to the rear of the table and a starting block to the front. Place the starting block so the saw will contact the place where the groove is supposed to start when the infeed end of the piece is against the block. Start the cut by holding the piece above the saw. Place the infeed end against the starting block and the edge against the fence. Lower the piece gently onto the saw blade. When the piece contacts the tabletop, feed it through to the stop block.

When you are cutting a rabbet, the cut into the face of the piece is the shoulder cut. The cut into the edge or end is the cheek cut. Make the shoulder cut first. Set the saw to extend above the table a distance equal to the desired depth of the shoulder. Set the fence a distance away from the saw equal to the desired depth of the cheek. Be sure to measure this distance from a sawtooth set to the left of, or away from, the ripping fence. If you measure it from a tooth set to the right of, or toward, the fence, the cheek will be too deep.

Place the face of the piece that was down for the shoulder cut against the fence and make the cheek cut. Make the cheek cut with the saw at the same height as for the shoulder cut if the depth of the shoulder and the depth of the cheek are the

same. Change the height of the saw if the depth of the cheek is different.

By using the dado head, you can cut most rabbets in a single cut. First, build up a dado head equal in thickness to the desired width of the cheek. Next, set the head to protrude above the table a distance equal to the desired depth of the shoulder. Clamp a l-inch board to the fence to serve as a guide for the piece. Set the fence so the edge of the board barely contacts the right side of the dado head. Set the piece against the miter gauge that is set at 90° to the saw blade. Now hold the edge or end to be rabbeted against the l-inch board and make the cut.

On jointers, a rabbeting strip on the outboard edge of the outfeed table depresses for rabbeting. The strip is outboard of the end of the cutterhead. To rabbet on a jointer, you depress the infeed table and the rabbeting strip the depth of the rabbet below the outfeed table. Set the fence the width of the rabbet away from the outboard end of the cutterhead. The unrabbeted part feeds onto the rabbeting strip when the piece feeds through.

Various combinations of the grooved joints are used in woodworking. The well-known tongue-and-groove joint is actually a combination of the groove and the rabbet. The tongued member is simply a member rabbeted on both faces. In some types of panel work, the tongue is made by rabbeting only one face. A tongue of this kind is a bare-faced tongue. The dado and rabbet joint (fig. 3-25) is another joint often used in making boxes, drawers, and cabinets.

The housed lock-joint (fig. 3-26) is a type of dado and rabbet joint. Note that the rabbeted piece is reversed. The dadoed piece extends beyond the rabbeted piece. This joint is used extensively in the pattern shop for manufacturing special wooden foundry flasks. The dadoed piece extends to form handles for the flask.

Dovetail Joints

The dovetail joint (refer to fig. 3-17) is the strongest of all the woodworking joints. However, its construction requires a lot of work; therefore, you will use dovetail joints only when working on finer grades of furniture and cabinet work.

A joint containing only a single pin is a single dovetail joint. A joint containing two or more pins is a multiple dovetail joint. A joint in which the pins pass all the way through the tail member is a through dovetail joint. A joint in which they pass only part way through is a blind dovetail.

The simplest dovetail joints is the half-lap dovetail joint (fig. 3-27). This joint is first laid out and cut like an ordinary end half lap. The end of the lapping member is laid out for shaping into a dove tail as follows:

● Set the T-bevel to 10°. This is the correct angle between the vertical axis and the sides of a dovetail pin or tail. You can set the bevel with a protractor or with the protractor head on the

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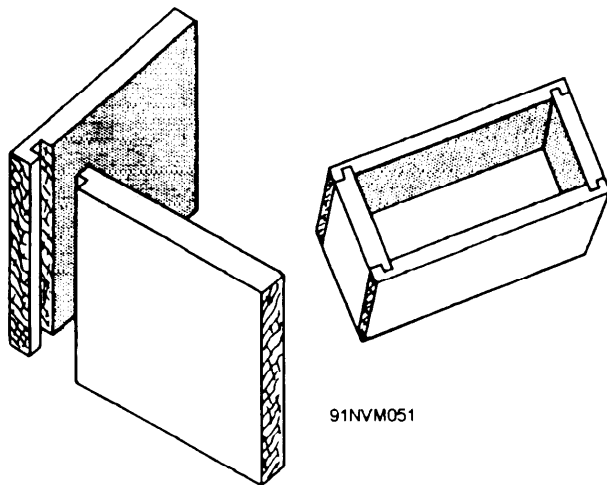
Figure 3-25.—Dado and rabbet joint.

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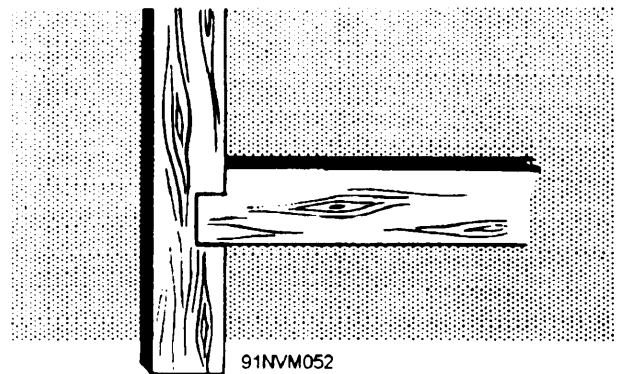
Figure 3-26.—Housed lock-joint.
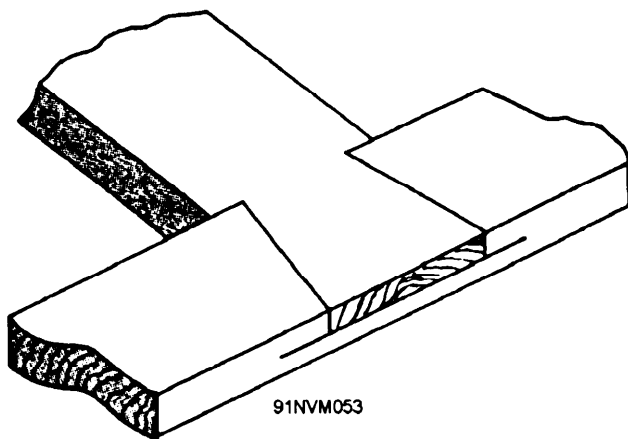
Figure 3-27.—Dovetail half-lap joint.

Figure 3-29.—Making a half-dovetail joint.

combination square. If you don't have either of these, use the method shown in figure 3-28.

● Select a board with a straight edge, square a line across it, and lay off six equal lengths on the line as shown. From the sixth mark, lay off one length perpendicular to the right. A line drawn from this point to the starting point of the first line drawn will form a lo-degree angle with that line.

● Lay off this angle from the end corners of the lapping member to the shoulder line (fig. 3-29). Saw out the waste as shown. The lapping member now has a dovetail on it. Place this dovetail over the other member, in the position it is supposed to

occupy, and score the outline of the recess. Then saw and chisel out the recess. Remember to saw on the waste side of all lines.

To make a multiple-dovetail joint, you lay out the end of the tail member as shown in figure 3-30. The strongest type of dovetail joint is one in which the pins and tails are the same size. For ease in cutting, the pins are usually somewhat smaller than the tails (as shown). To make a multiple-dovetail joint, you first determine the number of pins and the size you want to make each pin. Then, lay off a half-pin from each edge of the member. Next, locate the center lines of the other pins at equal intervals across the end of the piece. Then, you lay

Figure 3-28.—Laying off a 10-degree angle for a dovetail joint.
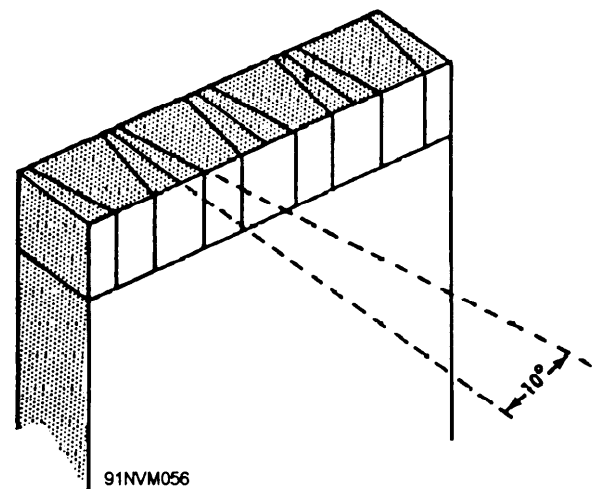
Figure 3-30.—Laying out pin member for through multiple-dovetail joint.
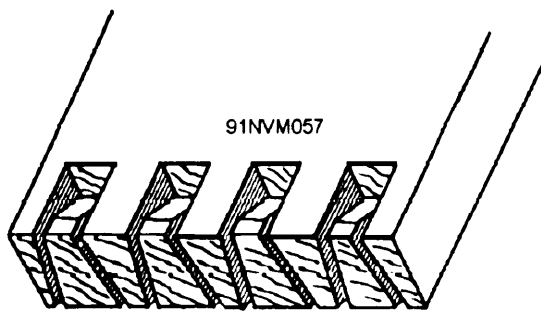
Figure 3-31.—Chiseling out waste in a through multiple-dovetail joint.

off the outlines of the pins at 10° to the center lines. Determine the depth of the shoulder line by the thickness of the tail member.

You cut out the pins by sawing on the waste sides of the lines and then chisel out the waste. You should chisel halfway through from one side, as shown in figure 3-31. Then turn the member over and chisel through from the other side.

When you have finished cutting out the pins, lay the tail member flat. Set the ends of the pins in exactly the position they are to occupy (fig. 3-32). Score the outlines of the pins, which will, of course, also be the outlines of the tails. Square lines across the end of the tail member. Saw and chisel out the waste between the tails.

Box Corner and Miter Joints

The box corner joint is the same as a multiple dovetail with one exception—the 10-degree angle (refer to fig. 3-18). A miter joint (refer to fig. 3-19) is made by mitering the ends or edges of the members that are to be joined. The angle of the miter cut is one-half of the angle formed by the joined members. In rectangular frames, door casings, boxes, and the like, adjacent members form a 90-degree angle. The correct angle for mitering is 45°. For members that will form an equal-sided figure with other than four sides (such as an octagon or a pentagon), you need to calculate the correct mitering angle. Do this by dividing the number of sides the figure will have into 180, as shown in figure 3-33.

You can miter members in a wooden or metal miter box or on the circular saw by setting the miter gauge to the desired angle. You can edge miter members to any angle on the circular saw by tilting the saw.

Abutting surfaces of end-mitered members do not hold well when merely glued. You need to reinforce them. A good reinforcement for a joint between end-mitered members is the slip feather. This joint is a thin piece of wood or veneer glued into a kerf cut in the thickness dimension of the

Figure 3-32.—Marking the tail member.

3-24
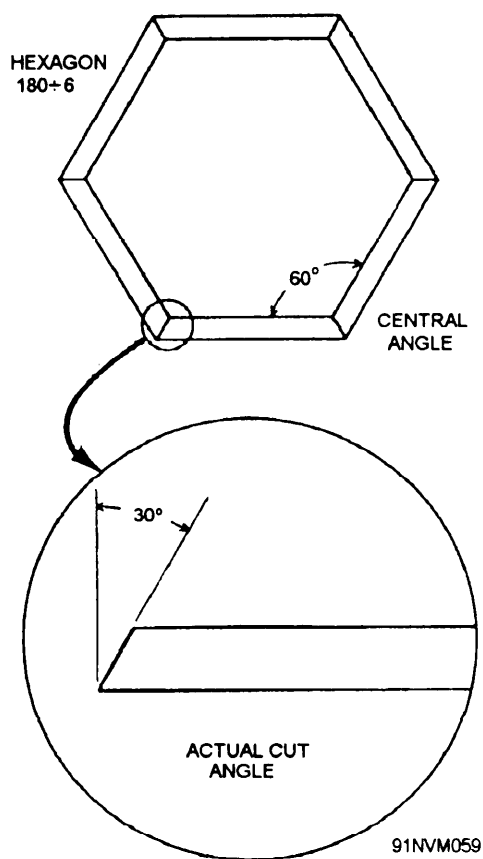
Figure 3-33.—Mitering angles.

joint. (See fig. 3-34 for a simple jig to use when making the kerf cut.) Saw about halfway through from the outer to the inner corner. Apply glue to both sides of the slip feather, and push the slip feather into the kerf (fig. 3-35). Clamp it tight and allow the glue to dry. After it has dried, remove the clamp and chisel off the protruding portion of the slip feather.

Coping Joints

Inside corner joints between molding trim members are usually made by placing the end of one member against the face of the other. Figure 3-36 shows the method of shaping the end of the abutting member to fit the face of the other members. First, saw the end of the abutting member square. Do this as you would an ordinary butt joint between ordinary flat-faced members. Then, miter the end to 45°, as shown by views A and B of figure 3-36. Set the coping saw at the top of the line of the miter cut. Hold the saw at 90° to the lengthwise axis of the piece. Saw off the segment as shown in view C. Closely follow the face

line left by the 45-degree miter cut. The ends of the abutting members will then match the face of the other member as shown in view D.

Mortise-and-Tenon Joints

The mortise-and-tenon joint is mostly used in furniture and cabinet work. In the blind mortise-and-tenon joint (refer to fig. 3-21), the tenon does not penetrate all the way through the mortised member. When the tenon penetrates all the way through, it is a through mortise-and-tenon joint. Besides the ordinary stub joint (fig. 3-37, view A), there are haunched joints (view B) and table-haunched joints (view C). Haunching and table-haunching increase the strength and rigidity of the joint.

MORTISE-AND-TENON LAYOUT.—You can lay out an ordinary stub mortise-and-tenon joint using the following steps:

1. Mark the faces of the members plainly.

2. Lay off the desired length of the tenon.

3. Square the shoulder line all the way around.

4. Then, lay off the total width of the tenon member on the mortise member, as shown in figure 3-38.

5. Determine the thickness of the tenon. It is usually between one-third and one-half the thickness of the mortise member.

6. Use a marking gauge to mark two lines (fig. 3-38). If the faces of the members are to be flush, use the same gauge setting to score a double line on the mortise member. Remember to gauge from the face of the member. If the face of the tenon member is to be set back from the face of the mortise member, you should increase the mortising gauge setting by the amount of the setback.

7. Last, lay off from the end of the mortise member and from the matching edge of the tenon member. Lay off by the amount of end stock that is to remain above the mortise.

NOTE: You wouldn't need this last step of the layout for a slip-tenon joint, like the one shown in figure 3-21.

91NVM060

JIG →

FRAME →

SAW BLADE

JIG →

SIDE VIEW

FRAME

MITER KERF JIG →

TABLE SAW RIP FENCE

SAW BLADE

SAW TABLE →

END VIEW
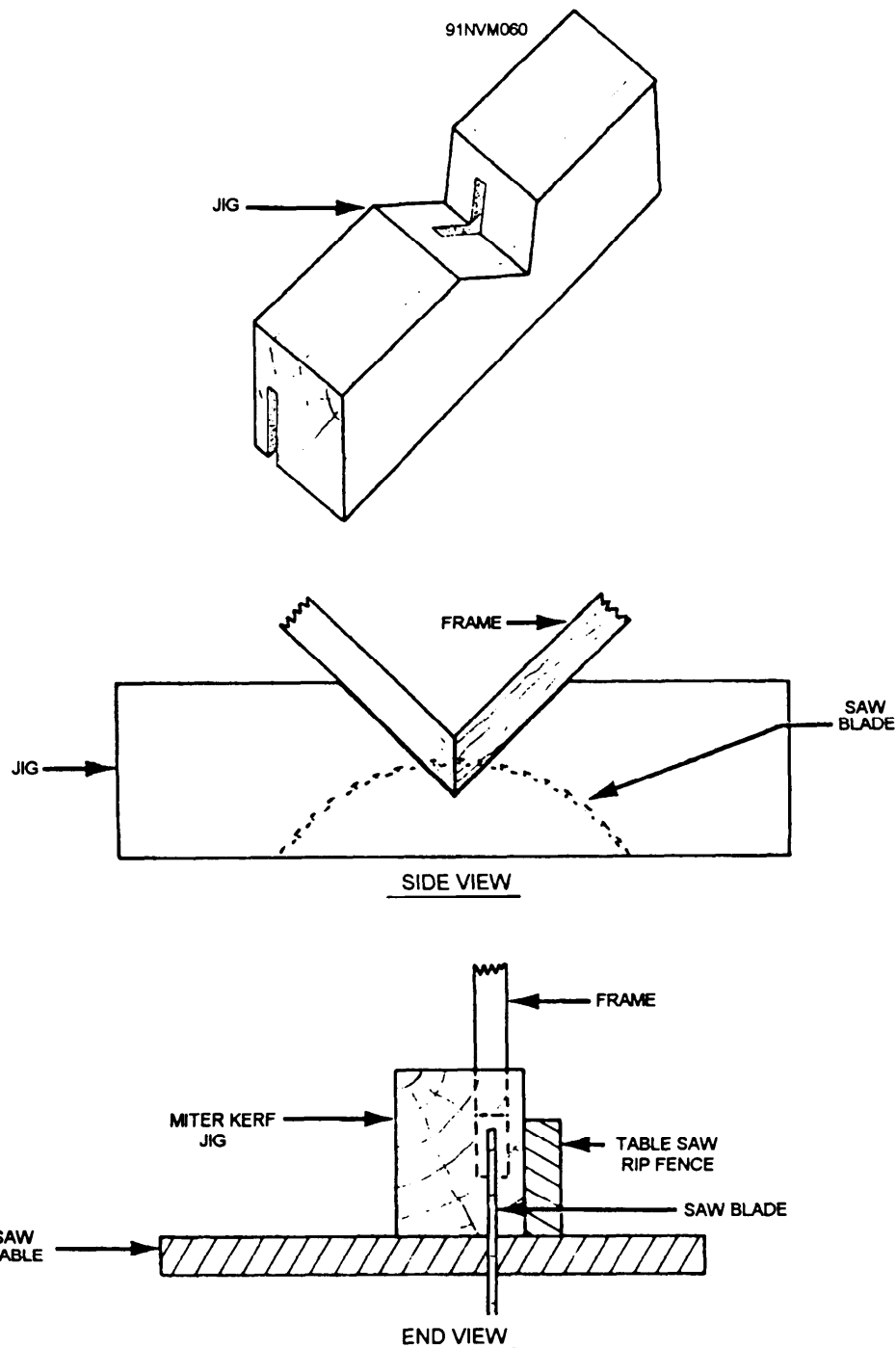
Figure 3-34.—Kerf jig for mitered joints.

CUTTING MORTISE-AND-TENON JOINTS.—You can cut tenons by hand with the backsaw by using the same method described for cutting corner and end half-lap joints. You can cut mortises by boring a series of holes slightly smaller than the width of the mortise. Then, you chisel out the remaining waste. For a blind mortise-and-tenon joint, use a depth gauge. Use of the depth gauge prevents the drill from boring below the correct depth of the mortise.

Look at figures 3-39 and 3-40 as you read the following steps on using a circular saw to cut tenons.

KERF CUT

SLIP FEATHER

SLIP FEATHER INSERTED INTO KERF

91NVM061

SLIP FEATHER SANDED SMOOTH WITH FRAME
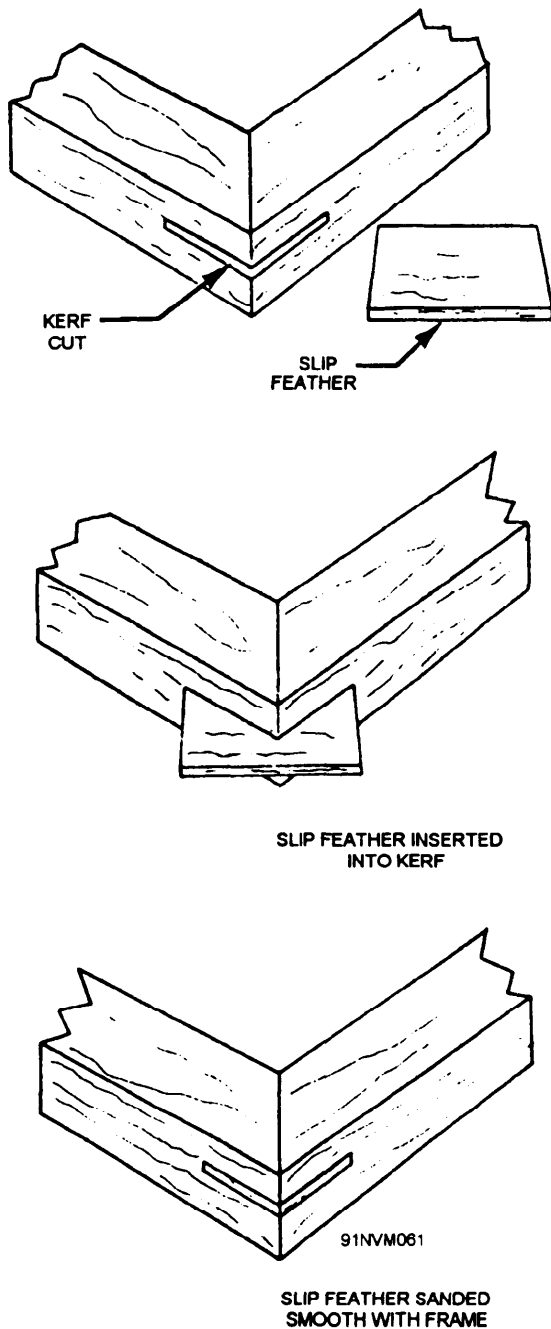
Figure 3-35.—Slip feather reinforcement.

1. Make the shoulder cuts first.

2. Set the saw the depth of the shoulder above the table.

3. Set the rip fence the length of the tenon away from the saw. Remember to measure from a sawtooth set to the left. Make the shoulder cuts, as shown in figure 3-39.

45° MITER CUT

91NVM062

A

90° ANGLE OF COPING SAW

B

FOLLOW THE CONTOUR

C

D
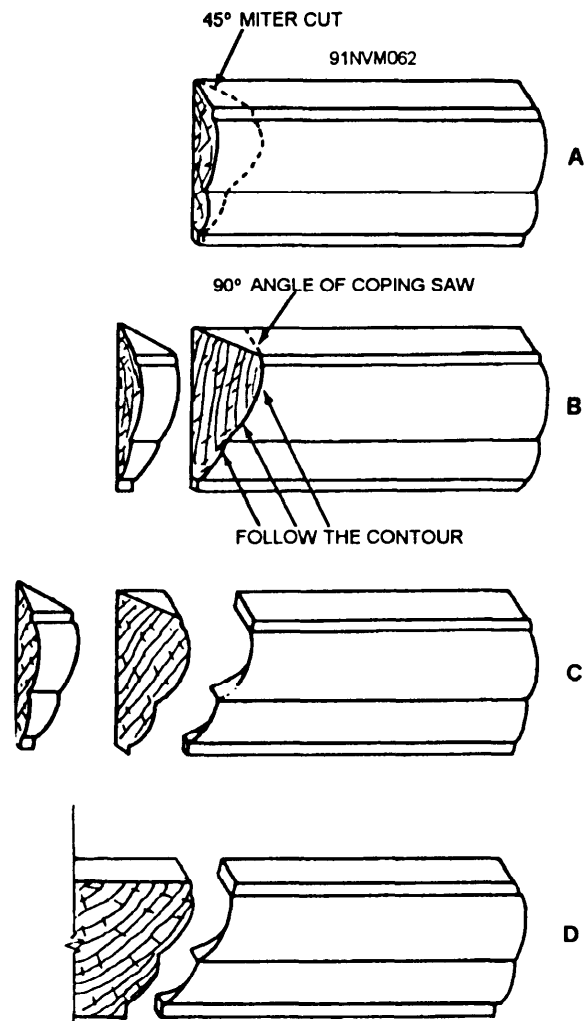
Figure 3-36.—Making a coping joint.

4. Set the saw the depth of the cheek above the table.

5. Set the fence the width of the shoulder away from the saw. Then make the cheek cuts, as shown in figure 3-40. To steady the stock against the fence, use a feather board like the one shown clamped to the table. To maintain the stock upright, use a push board, like the one shown in figure 3-40.

You can also use a dado head to cut tenons. Use the same method described before for cutting end half-lap joints.

A hollow-chisel mortising machine cuts mortises mechanically. The cutting mechanism on this machine consists of a boring bit encased in a square hollow steel chisel. As the mechanism presses into
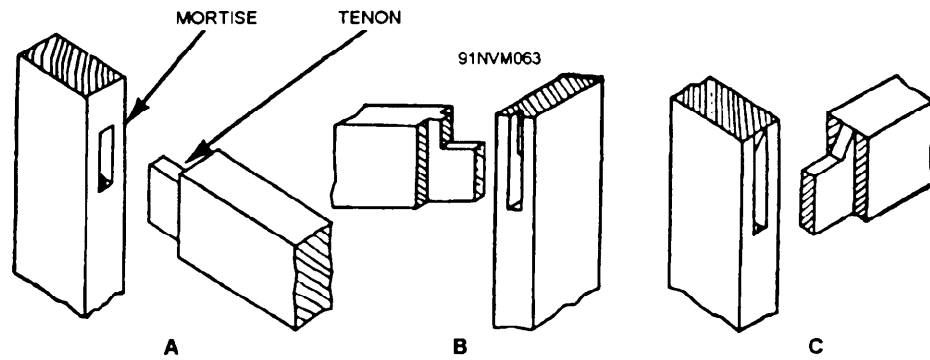
Figure 3-37.—Mortise-and-tenon joints. A. Stub. B. Haunched. C. Table-haunched.
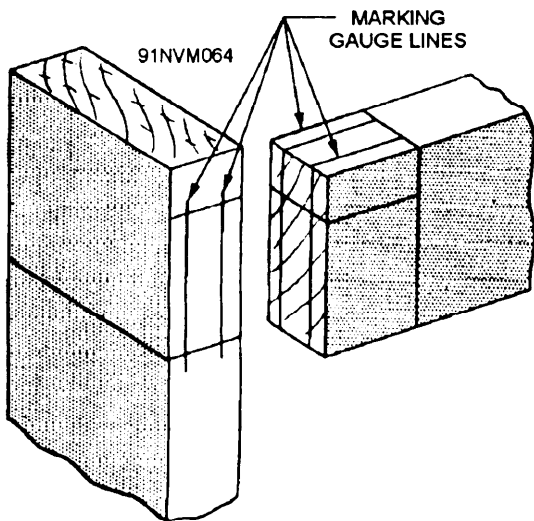
Figure 3-38.—Layout of a stub mortise-and-tenon joint.
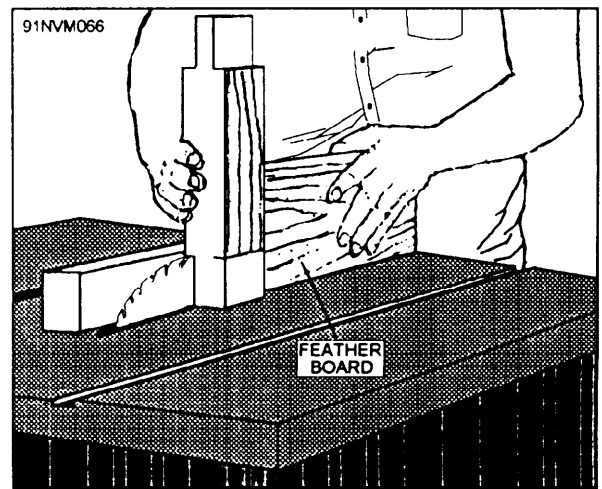
Figure 3-40.—Using a feather board and push board to steady stock when cutting a tenon cheek.
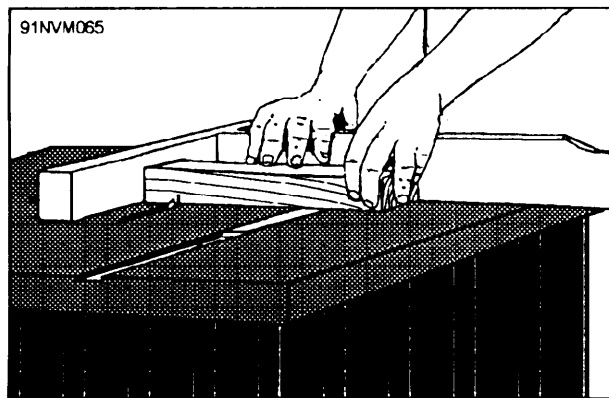
Figure 3-39.—Gutting a square-shouldered tenon.

the wood, the bit takes out most of the waste. The chisel pares the sides of the mortise square. Chisels come in various sizes with bits to match.

Fasten mortise-and-tenon joints with glue and additional fasteners as required. One or more wood or metal dowels may be driven through the joint to give strength to the joint.

JOINT APPLICATIONS

Plywood panels are installed in frames to make parts of doors, partitions, bulkheads, and many other items. The panels can be installed by several methods. Four commonly used methods are shown in figure 3-41. Notice in figure 3-41, views A and B,
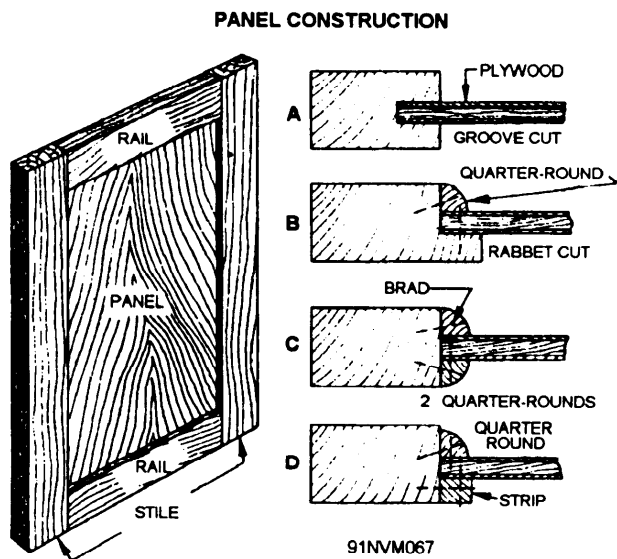
Figure 3-41.—Panel construction.

how a groove and rabbet set the panel into the rails and stiles. Join the rails and stiles by using dowels, miter joints, half-lap joints, or mortise-and-tenon joints.

Standard methods of making a table are shown in figures 3-42 through 3-46. Make desks in much the same manner but with the addition of panels and more drawers.
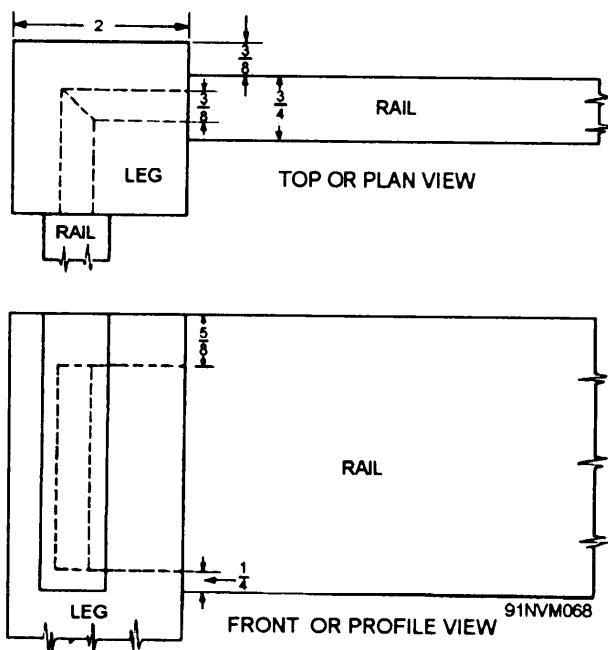
Figure 3-42.—Mortise-tenon layout and design.

BUTT JOINT
WITH CORNER PLATE AND LAG SCREW
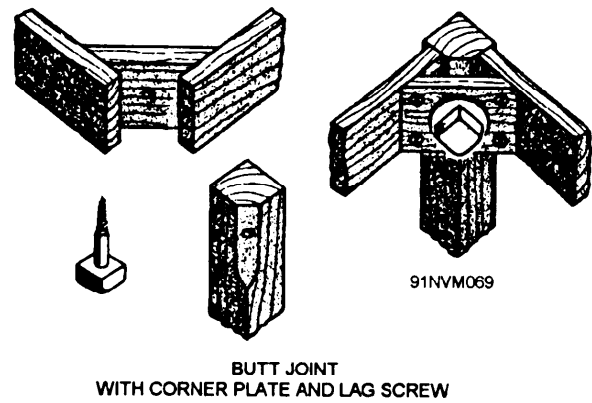
Figure 3-43.—Comer butt joint for table legs.

Figure 3-42 shows the layout and design for mortise-and-tenon joints. Mortise-and-tenon joints join the table rails to the legs (fig. 3-43) and secure the stretcher to the lower end rails. An alternate method of securing the legs to the rails is by corner plates and lag screws. Using this method, the legs tighten easily when they become loose. They also remove easily for storage or moving.

Make drawers for tables and desks by the method shown in figure 3-44. You will find it easier to make drawers by this method than by making them with dovetail joints. However, dovetail joints are better and should be used on jobs made of fine cabinet woods. Use blind dovetails for the front corners of drawers made for such furniture.
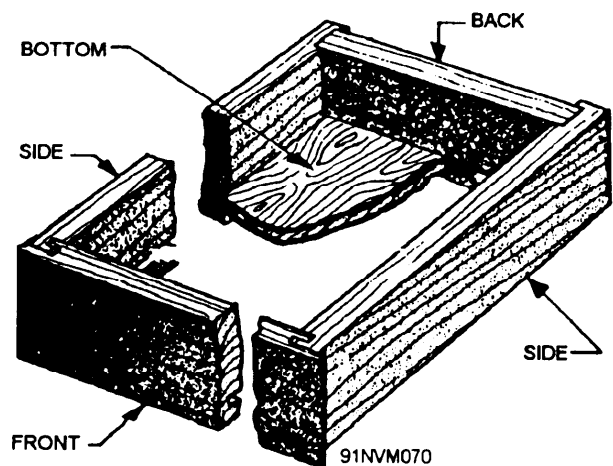
Figure 3-44.—Simple drawer construction.

3-29
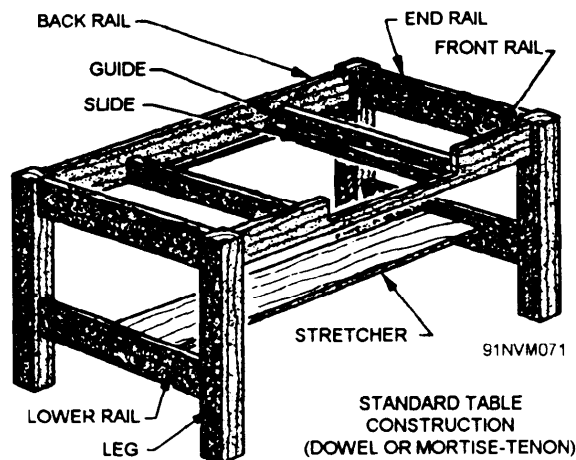
Figure 3-45.—Standard table construction.

Tabletops usually fasten to the upper rails (fig. 3-45) by one of the six standard methods shown in figure 3-46. You will probably use the cleat more than any of the others. Fasten the cleat screws to the rail first so it is about 1/16 inch below flush. Then, the screws going into the top will pull the top down tight and snug.

FASTENING MATERIALS

Many kinds of fasteners hold wood together. These include glue, nails, screws, bolts, and special fasteners.

TYPES OF GLUE

The two most commonly used glues in today's pattern shop are urea resin glue and vinyl resin (white) glue.

Urea resin glue is a synthetic compound that comes either in a powder mixed with water or a

Figure 3-46.—Securing rails to tabletops.

powder mixed with another solution. It is a water-resistant glue that works well on hardwoods. It is a cold-working glue that sets within 24 hours at room temperature (70°F). Urea resin glues set and harden by the condensation of the resin.

Vinyl resin glue is a synthetic thermoplastic white liquid. It requires no mixing or heating before use. This glue comes ready to use and can be applied at temperatures above 50°F. The initial setting of the glue takes less than 30 minutes. A strong bond will occur in less than 1 hour for ordinary work. In addition, this glue is compounded to reduce wear on cutting tools. It also has a glue line that is practically colorless. For general construction, vinyl resin glue has replaced all glues that require heating, cooking, or mixing.

Pointers on Using Glue

Prepare and use each type of glue in a specific manner. Instructions and safety precautions are always given on the label of the container, or on the MSDS for the glue. You should study these carefully before trying to use any glue. Certain rules should be followed in the application of all glues.

The wood should be room temperature (70°F). If the wood is cold, the glue next to the wood chills and sets before it has penetrated the pores of the joint. If the wood is hot, the water in the wood will expel, causing the joint to warp. Glues give best results when the wood is at room temperature.

Squeeze or rub excess glue out of a joint before applying pressure. Always apply pressure as quickly as possible after spreading the glue. This prevents the glue from setting before the excess can be squeezed out. The greater the pressure applied, the stronger the joint will be.

NOTE: Do not apply so much pressure that the wood crushes.

If possible, the pressure should be at least 100 psi. Squeezing out too much glue is impossible. Clamps alone produce this pressure, but they do not distribute the pressure evenly. To get a joint with maximum strength, you should use plates between the clamps and the wood.
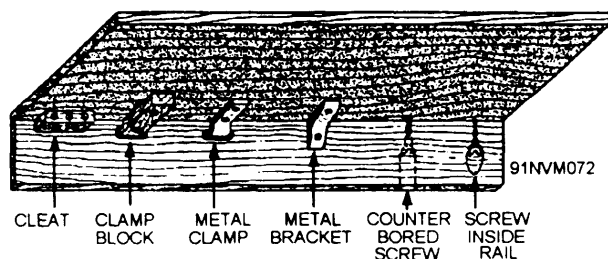
Methods of Applying Glue

When you need thicker or wider material but it is not available, you will have to glue several pieces of material together. The two principal methods used for gluing wood stock are face-to-face gluing and edge-to-edge gluing.

In face-to-face gluing, first determine the sizes of stock needed. Then, you should decide what available stock can be glued up to produce the required size. Remove enough lumber from the rack to do the job. Saw the lumber to the required lengths. Dress one face and one edge of each piece of material on the jointer. Dress the material to the proper thickness in the planer. Rip the pieces to the proper width in the circular saw. Adjust the hand clamps to an approximate jaw opening. Lay the stock on the bench and fit each clamp loosely over the stock. Then place them in a spot where they can be easily reached.

Place the stock in the desired gluing position. Alternate in relation to the growth rings. The warpage of each piece offsets the warpage of the one next to it if this arrangement is followed. Also, arrange the pieces so the grain of their respective surfaces runs in the same direction. Otherwise, difficulties may arise later when dressing the job to proper thickness. Planing with the grain on one part of the surface may prove to be the wrong direction for an adjacent area.

After proper arrangement, use some system of marking the pieces of stock. This is so they will not be disarranged during the gluing-up process. Apply a good coat of glue to the surface of the piece of stock lying face up. Place one of the other pieces of stock face-to-face with the glued surface. Rub back and forth or in a circular motion. Exert as much down pressure as possible. This spreads the glue evenly throughout the joint and helps prevent air bubbles. In addition, a certain amount of glue is driven into the pores of the wood. The glued surfaces are pulled closer together. Repeat the preceding gluing operations until all pieces are assembled

Position clamps and tighten glued-up stock as shown in figure 3-47. Place clamp A in a position so that when the clamps are all in place, the space between them will be somewhat equal throughout the length of the material. Keep lower clamp spindle M at least 1/2 inch above the surface of the material. Tighten up on spindle M and release spindle N until a fair amount of pressure is on that part of the jaws near M. Next, turn spindles M and N until the entire face of jaw F is exerting an even pressure on the face of the material. Use enough force to squeeze excess glue from the joints of the glued-up stock and draw all surfaces tightly together.

Adjust and tighten clamp B just like clamp A. As each clamp is added, the glue is forced along, as well as out of, the joint. If the ends are clamped first, a large amount of glue is trapped in the
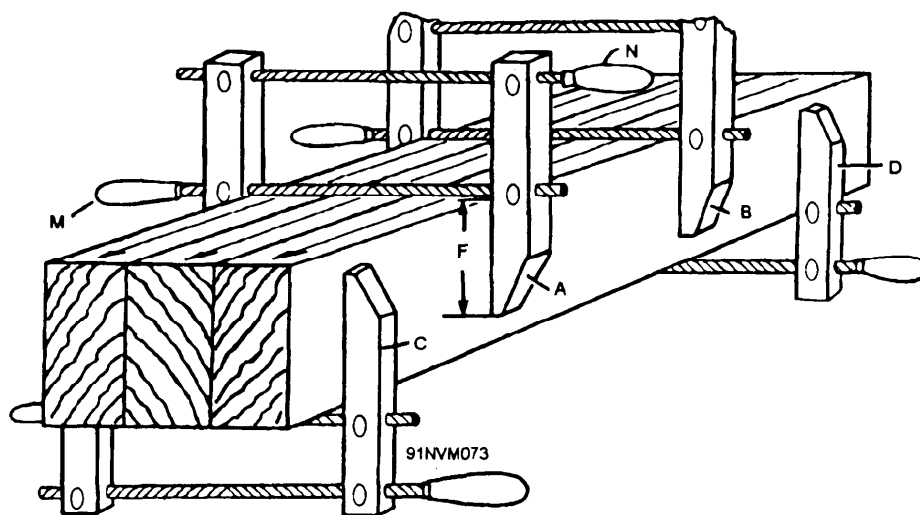

Figure 3-47.—Face-to-face gluing.

middle. This is especially true when you are gluing up wide pieces of material. Next, turn the stock completely over on a table or bench so it rests on the ends of clamps A and B. Place clamps C and D, and adjust the same as clamps A and B.

NOTE: Clamping the midsection of the material first will give the excess glue squeezed out of the joint more outlets.

Now examine the job carefully to see that all the clamps are properly set and that all the glued joints have been properly drawn up. Remove the job to a convenient spot where it will be out of the way until needed. If the job stays on the bench, excess glue squeezed from the joint will stick to the bench top. You should clean all waste glue from the top of the bench.

When the glue has jelled, remove it with a glue scraper. Then wipe the surface with a piece of cloth dipped in hot water. If it is a rush job, the clamps may be removed in 4 hours. However, the joints cannot be guaranteed to hold if the clamps are removed too soon. Best results will result from clamps left on for 12 hours. You should plan construction of the job to provide time for good results in gluing operations.

The edge-to-edge method of gluing up stock has two purposes. It is used most often to get material that will be thin in comparison with its width. Use this method to glue up material that has to be wider than any on hand.

In edge-to-edge gluing, select, dress, and rip the material the same way as you did for face-to-face gluing. Set the clamp jaw openings to suit the width of the assembled pieces of stock. Allow for blocks on the edges of the material to prevent marring. Make two jig blocks for each of the bottom clamps (fig. 3-48) to hold the clamps upright during the gluing operations. Again, note the arrangement of pieces so the annual ring growth will tend to offset warpage. Be sure the direction of the grain is the same in all the pieces to be glued.

Place glue on the edges of the boards you are joining. Rub the stock together to spread the glue evenly and force out any air bubbles. If the ends of the joints come apart before tightening the clamps, use pinch dogs to hold the boards together temporarily. Put the middle clamps in place with the blocks in front of the jaws. Adjust and tighten them. Then adjust and tighten the clamps on the ends, squeezing out all excess glue.

Inspect the clamps every few hours to make sure the stock is not warping. If any of the edges pull apart before the glue has dried, adjust the clamps to apply equal tension throughout.

NAILS, BRADS, DOWELS, AND CORRUGATED FASTENERS

Fastening materials such as nails, brads, dowels, and corrugated fasteners work in combination with glue in pattern construction. Many of the materials used in the HT rating are the same as those found in other woodworking trades. Nails provide the least holding power, screws provide better, and bolts provide the best holding power of all. Wood screws may be combined with glue and paper in parted pattern turning. Use dowels for the alignment of
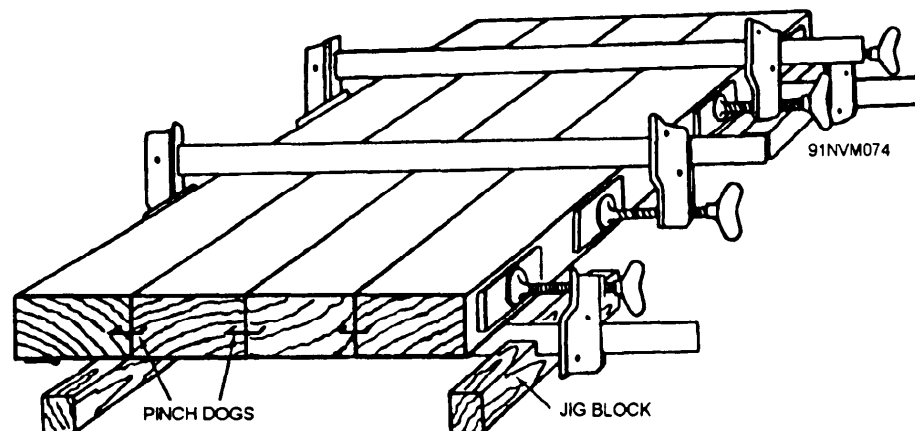

Figure 3-48.—Edge-to-edge gluing.

parted patterns and of loose pattern parts. A description of these fasteners is given in the following paragraphs.

Nails and Brads

There are many types of nails, which are classified according to use and form. They vary in size, shape of head, type of point, and finish. Nail sizes are described by the term *penny*. The penny sets the length of the nail (one penny, two penny, and so on) and is the same for all types. The approximate number of nails per pound varies with the type and size. The wire gauge number varies with type. Figure 3-49 provides the information related to the term *penny* for each nail type

COMMON WIRE NAILS

SIZE	LENGTH AND GAUGE		APPROXIMATE NUMBER TO POUND
	INCHES	NUMBER	
A 60d	6	2	11
B 50d	5 1/2	3	14
C 40d	5	4	18
D 30d	4-1/2	5	24
E 20d	4	6	31
F 16d	3-1/2	7	49
G 12d	3-1/4	8	63
H 10d	3	9	69
I 9d	2 3/4	10-1/4	96
J 8d	2-1/2	10-1/4	106
K 7d	2-1/4	11-1/2	161
L 6d	2	11-1/2	181
M 5d	1-3/4	12-1/2	271
N 4d	1-1/2	12-1/2	316
O 3d	1-1/4	14	568
P 2d	1	15	876

91NVM075
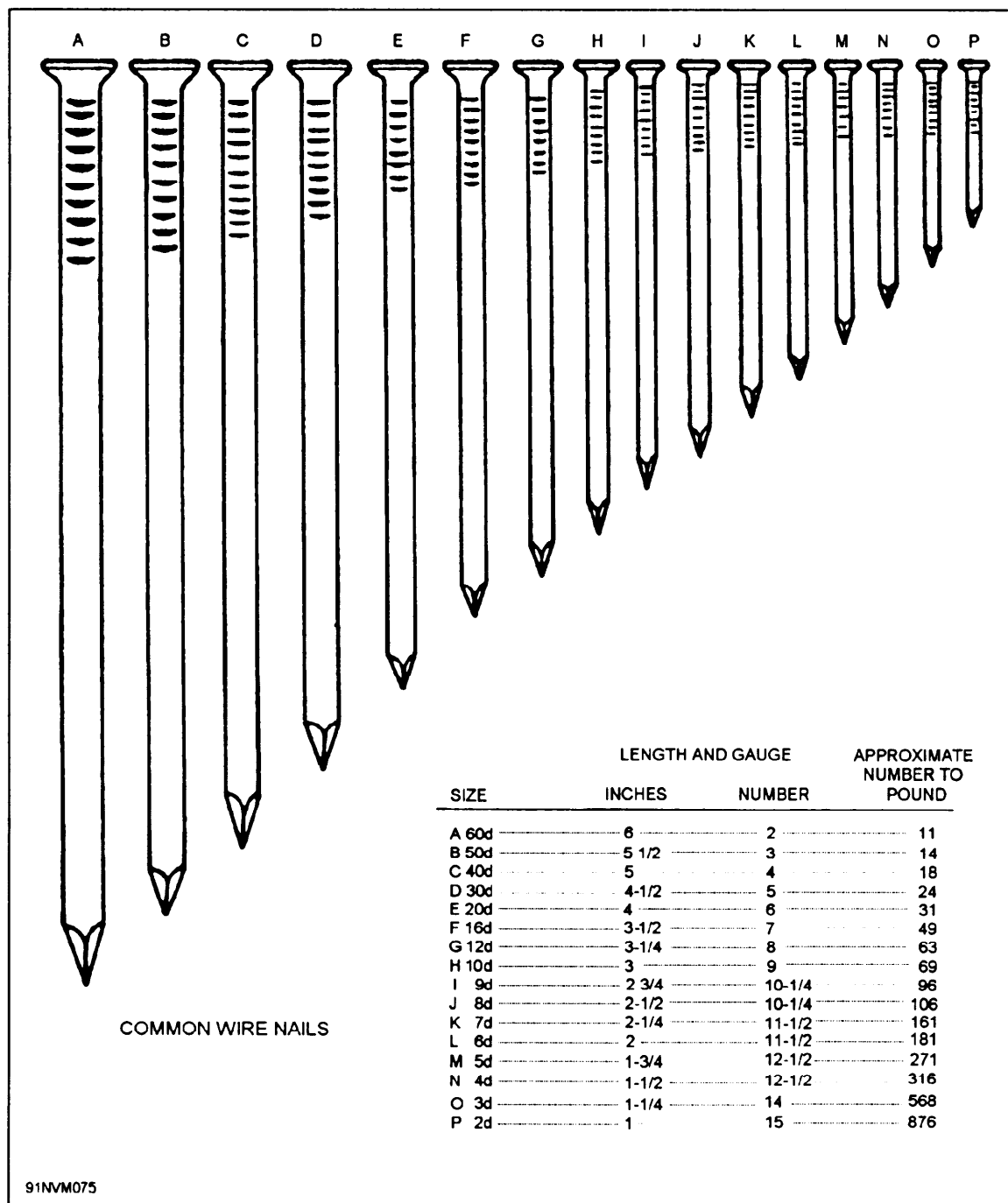
Figure 3-49.—Types of nails and nail sizes.

referenced in this section. The **d** next to the numbers in the size column is the accepted abbreviation of the word *penny,* as used in nail sizing. It reads two penny, three penny, and so on.

A few rules should be followed when you use nails. For maximum holding power, a nail should be at least three times as long as the thickness of wood it is to hold. Two-thirds of the length of the nail is driven into the second piece for proper anchorage. One-third provides the necessary anchorage of the piece being fastened. Nails should be driven at a slight angle toward each other. Place them carefully to provide the greatest holding power. Nails driven with the grain do not hold as well as nails driven across the grain. A few nails of proper type and size, properly placed and driven, will hold better than many nails poorly placed. Nails are the cheapest and easiest fasteners to use.

The common wire nail (fig. 3-50, view A) has a flat head. It ranges in size from 2d (1 inch long) to 60d (6 inches long). The box nail (fig. 3-50, view B) has the same length per penny size as the common wire nail. It has a lighter head and smaller diameter. In structural carpentry where appearance is not important, you should use both the common wire and box nail.

A - COMMON WIRE NAIL

B - BOX NAIL

C - FINISH NAIL

D - DUPLEX NAIL

91NVM076

E - WIRE GAUGE BRAD
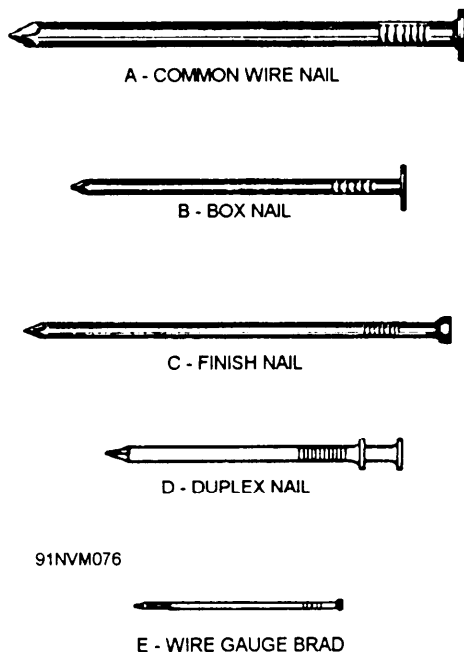
Figure 3-50.—Nails and brads.

The finish nail (fig. 3-50, view C) is made from finer wire than either the common wire or box nail. Its length per penny size is the same. The finish nail has a small head that may be set below the surface of the wood. The small hole that remains may be puttied or waxed over. You should use finish nails where appearance is important.

The duplex nail (fig. 3-50, view D) is a temporary fastener so it has two heads. The lower head, or shoulder, is driven securely home to give maximum holding power. The upper head projects above the surface of the wood to make it easy to remove.

The wire gauge brad (fig. 3-50, view E) comes in several gauges for the same length of brad. It ranges in length from 3/8 inch to 6 inches. It is the most suitable brad for pattern work. Remember that for brads, the higher the gauge number, the smaller the body diameter. Length and wire gauge identify its size. For example, 1–12 means 1 inch long and made of 12-gauge wire (0.105 inch), while 1 1/2—15 means 1 1/2 inches long and made of 15-gauge wire (0.072 inch).

Wood Screws

Several factors dictate the use of wood screws rather than nails and may include the type of material being fastened and the holding power requirements. Other factors could be the finished appearance desired and limits to the number of fasteners used. Using screws rather than nails is more expensive in time and money, but their use is often necessary to meet specifications.

The main advantages of screws are they provide more holding power and tighten easily to draw the items fastened securely together. They are also neater in appearance if properly driven and may be withdrawn without damaging the material. The common wood screw is made from unhardened steel, stainless steel, aluminum, or brass. Unhardened steel or brass screws are normally used in the pattern shop. Wood screws are threaded from a gimlet point for about two-thirds the length of the screw. They have a slotted or Phillips head designed to be driven by a screwdriver.

Wood screws (fig. 3-51) are classified according to head style. The most common types are flat head, oval head, and round head, both in slotted and Phillips heads.
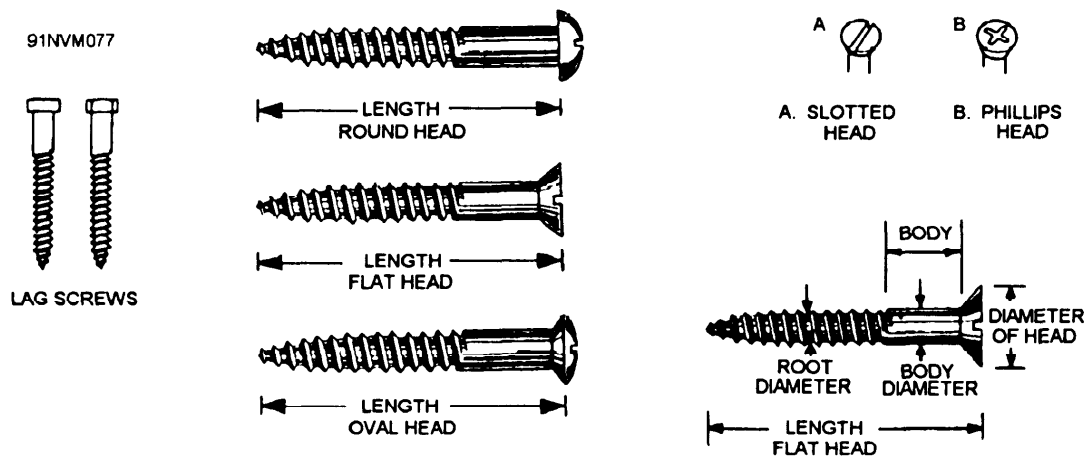
Figure 3-51.—Types of wood screws and nomenclature.

To prepare wood for receiving the screws, you bore a pilot hole the diameter of the screw in the piece of wood to be fastened (fig. 3-52). Then bore a smaller starter hole in the piece of wood that is to act as anchor to hold the threads of the screw. Drill the starter hole with a smaller diameter than the screw threads. Go to a depth one-half or two-thirds the length of the threads to be anchored. The purpose of this careful preparation is to assure accuracy in the placement of the screws. It also reduces the chance of splitting the wood and reduces the time and effort required to drive the screws.

Properly set slotted and Phillips flat-head and oval-head screws are countersunk enough to permit covering the head. Round-head screws are driven so the head is firmly flush with the surface of the wood. The slot of the round-head screw is parallel to the grain of the wood.

Wood screws come in sizes that vary from 1/3 inch to 6 inches. Screws up to 1 inch in length increase by eighths. Screws from 1 to 3 inches increase by quarters. Screws from 3 to 6 inches increase by half inches. Screws also vary in shaft size. Proper nomenclature of a screw is shown in figure 3-51. This includes the type, material, finish, length, and screw size number. The screw size number shows the wire gauge of the body, drill, or bit size for the body hole. It also shows drill or bit size for the starter hole. Tables 3-3 and 3-4 provide size, length, gauge, and applicable drill and auger bit sizes for screws.
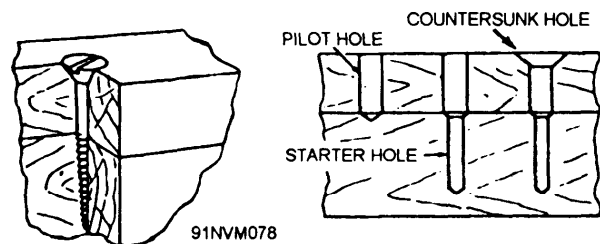
Figure 3-52.—Sinking a screw properly.

The proper name for lag screws (fig. 3-51) is lag-bolt wood screw. Building construction often requires you to use these screws. Lag-bolt wood screws are longer and much heavier than the common wood screw and have coarser threads. The threads extend from a cone or gimlet point slightly more than half the length of the screw. Square-head and hexagon-head lag screws are always externally driven, usually by a wrench. They are used when ordinary wood screws would be too short or too light.

Dowels

HTs use dowels to assemble and hold loose parts of a pattern in proper relation to each other while ramming up the pattern. Dowels often reinforce glued joints and delicate parts of a job. Wood dowels are round wooden pins made from straight-grained maple or birch. The diameters commonly used in the shop range from 1/8 to 1 inch, in 1/8-inch increments.

3-35

Table 3-3.—Screw Sizes and Dimensions

91NVM079 LENGTH (IN.)	SIZE NUMBERS																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	22	25
1/4	x	x	x	x																		
3/8	x	x	x	x	x	x	x	x	x	x												
1/2			x	x	x	x	x	x	x	x	x	x	x	x								
5/8			x	x	x	x	x	x	x	x	x	x	x	x		x						
3/4				x	x	x	x	x	x	x	x	x	x		x		x					
7/8			x	x	x	x	x	x	x	x	x	x	x		x		x					
1				x	x	x	x	x	x	x	x	x	x		x		x		x	x		
1-1/4					x	x	x	x	x	x	x	x	x		x		x		x	x		x
1-1/2					x	x	x	x	x	x	x	x	x		x		x		x	x		x
1-3/4						x	x	x	x	x	x	x	x		x		x		x	x		x
2						x	x	x	x	x	x	x	x		x		x		x	x		x
2-1/4						x	x	x	x	x	x	x	x		x		x		x	x		x
2-1/2						x	x	x	x	x	x	x	x		x		x		x	x		x
2-3/4							x	x	x	x	x	x	x		x		x		x	x		x
3							x	x	x	x	x	x	x		x		x		x	x		x
3-1/2									x	x	x	x	x		x		x		x	x		x
4									x	x	x	x	x		x		x		x	x		x
4-1/2													x		x		x		x	x		x
5													x		x		x		x	x		x
6															x		x		x	x		x
THREADS PER INCH	32	28	26	24	22	20	18	16	15	14	13	12	11		10		9		8	8		7
DIAMETER OF SCREW (IN.)	0.060	0.073	0.086	0.099	0.112	0.125	0.138	0.151	0.164	0.177	0.190	0.203	0.216		0.242		0.268		0.294	0.320		0.372

Metal dowels (usually brass) are sometimes used. They do not damage easily, and they do not absorb moisture from the molding sand.

Metal dowels (fig. 3-53) are self-centering. The lower portion of the threaded end locates its own center in the bored hole. It also holds the dowel to

Table 3-4.—Drill and Auger Bit Sizes for Wood Screws

SCREW SIZE NO.		1	2	3	4	5	6	7	8	9	10	12	14	16	18
NOMINAL SCREW		0.073	0.086	0.099	0.112	0.125	0.138	0.151	0.164	0.177	0.190	0.216	0.242	0.268	0.294
BODY DIAMETER		$\frac{5}{64}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{7}{64}$	$\frac{1}{8}$	$\frac{9}{64}$	$\frac{5}{32}$	$\frac{11}{64}$	$\frac{11}{64}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{15}{64}$	$\frac{17}{64}$	$\frac{19}{64}$
PILOT HOLE	DRILL SIZE	$\frac{5}{64}$	$\frac{3}{32}$	$\frac{7}{64}$	$\frac{7}{64}$	$\frac{1}{8}$	$\frac{9}{64}$	$\frac{5}{32}$	$\frac{11}{64}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{17}{64}$	$\frac{19}{64}$
	BIT SIZE	—	—	—	—	—	—	—	—	—	—	—	4	4	5	5
STARTER HOLE	DRILL SIZE	—	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{5}{64}$	$\frac{5}{64}$	$\frac{3}{32}$	$\frac{7}{64}$	$\frac{7}{64}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{9}{64}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{13}{64}$
91NVM080	BIT SIZE	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4
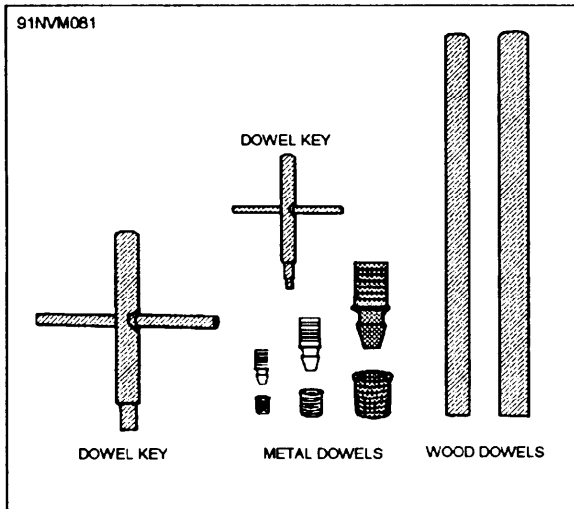
Figure 3-53.—Dowels and dowel keys.

its center as the threads cut their way into the wood. The thread depth keeps the dowel tight. The male and female parts fit within 0.001 inch.

You can easily insert or remove the metal dowel from the pattern by using a dowel key (fig. 3-53). Table 3-5 lists the dowel number size, the diameter of the dowel pin, and the recommended drill size.

Table 3-5.—Drill Sizes for Metal Dowels

Dowel No. Size	Dowel Diameter (inches)	Drill Size
0	7/64	1/8
1	11/64	3/16
2	3/16	1/4
3	7/32	5/16
4	5/16	6/16
5	13/16	9/16
6	17/32	3/4
7	13/16	1

Corrugated Fasteners

Corrugated fasteners are metal strips bent into many W shapes. These fasteners are used to butt two pieces of wood together. One-half the corrugated fastener goes on the first piece, the other half goes on the second. They are driven into the wood like a nail; but unlike a nail, they are not intended to be removed. The wood is destroyed if you try to remove a corrugated fastener. The most common application for corrugated fasteners is for holding together picture frames. The fastener is occasionally placed on the back side of the wood, but normally it is used like a slip feather.

FINISHING

The sequence of steps you should follow to complete a project is discussed in the following sections. A brief list of the steps follows. Sand the pattern to remove tool marks and ridges before it receives its final protective coating. Add fillets and include identification markings. Set rapping and lifting plates into the pattern.

SANDING MATERIALS

You need to use the correct sandpaper for the sanding job on which you are working.

Sandpaper is graded by the coarseness or fineness of the abrasive particles used on the paper. The grade is marked by a number on the back of the sandpaper. Table 3-6 shows sandpaper sizes and their suggested uses. Sandpaper usually comes in 9-inch by 11-inch sheets. For machine sanders, it comes either in rolls or cut to fit the machine.

Proper storage of sandpaper is important. Never store it in an area that is too damp or too dry. Moisture loosens the abrasive material, while excessive dryness makes the paper too brittle.

SANDING METHODS

Hand and lathe sanding are the two methods of finish sanding that you will routinely use. When you first started your pattern, you rough sanded pattern parts on power sanders made to remove large amounts of wood quickly. Finish sanding requires the careful removal of small amounts of wood in selected spots.

Table 3-6.—Abrasive Recommendations

KIND OF STOCK	STOCK REMOVAL		STOCK REMOVAL WITH FAIR FINISH		FINE FINISH	
	GRIT TYPE	GRIT SIZE	GRIT TYPE	GRIT SIZE	GRIT TYPE	GRIT SIZE
Paints and garnishes	Cabinet paper (opencoat garnet)	{ 2 1/2- 1 1/2			Wet paper "A" wight (silicon carbide)	{ 240-400
Hard tough minerals and compositions	Metal working cloth (aluminum oxide)		Metal working cloth (aluminum oxide)	{ 80-120	Finishing PaPer (aluminum oxide)	{ 150-320
Hard brittle mineral and compositions	Cabinet paper (aluminum oxide)	{ 50-80	Finishing Paper (aluminum oxide)	{ 100-180	Wet paper "A" weight (silicon carbide)	{ 220-320
Hard metals	Metal working cloth (aluminum oxide)	{ 40-60	Metal working cloth (aluminum oxide)	{ 80-120	Metal working cloth in oil (aluminum oxide)	{ 150-320 or crocus
Soft metals	Metal working cloth (aluminum oxide)	{ 36-60	Cabinet Paper (aluminum oxide)	{ 80-120	Wet paper "A" weight (silicon carbide)	{ 150-320
Hard wood Hard compositions Wallboards, etc.	Cabinet paper (aluminum oxide)	{ 36-50	Cabinet paper (aluminum oxide)	{ 60-100	Finishing PaPer (aluminum oxide)	{ 120-180
Plastics	Cabinet paper (aluminum oxide)	{ 60-100	Wet paper "C" wight (silicon carbide)	{ 120-220	Wet paper "A" wight (silicon carbide)	{ 240-600
Soft wood Soft wallboard	Cabinet Paper (garnet)	{ 2-1	Cabinet Paper (garnet)	{ 1/2-2/0	Finishing Paper (garnet)	{ 3/0-5/0

HAND SANDING

Normally, you sand the finished surfaces of cabinet and jointer work with the grain. Sanding with the grain avoids scratches that might spoil the natural appearance of the wood grain.

Redwood and some pines have a marked difference in hardness between the soft and hard portions of their growth rings. The abrasive on the sandpaper removes the softer portion of the grain quite rapidly when sanding is done with the grain on this type of wood. The harder grain portions offer

more resistance to the abrasive. Instead, they tear the abrasive from the paper. This loose material, in turn, wears the softer portions of the wood. This produces a washboard surface that is not acceptable for a pattern. When the same woods are sanded across the grain, the abrasive material rapidly cuts tiny chips out of the hard fiber walls. The entire abrasive face of the sandpaper dulls evenly. It cannot remove the soft grain portion any faster than the reduction of the hard fibers will permit.

For sanding flat surfaces, you should select a sheet of sandpaper that is just coarse enough to dress the surface free of tool marks without cutting the surface too rapidly. Then, tear or cut a sheet of sandpaper into four equal parts since it is too large for the average-size job.

Make a sandpaper block and fold one of the pieces of sandpaper around it. Sand the surface by moving the block back and forth across the grain with long strokes. Move along the surface from one end of the material to the other. Do not sand in one spot. Try to remove an equal amount from all parts of the surface during each sanding motion. Brush the surface free of wood dust and loose abrasives. Examine the surface for tool marks. If they are not all removed, repeat these sanding operations until you get the desired results. Complete sanding of the surface with a fine grade of sandpaper, then brush the surface clean.

When sanding straight narrow edges, sand with the grain of the wood. Most people use a rocking motion with a sanding block when cross-grained sanding on narrow edges. The rocking motion produces a rounded surface.

When sanding concave surfaces, use a round-faced block. Do as much cross-grained sanding as you can. Start each sanding stroke at the top edge of the concave surface and push toward the bottom. Do not sand on the back stroke. You may pass over the edge and knock the corner over. Clean the surface often during sanding and look for tool marks. Finish the surface with a fine grade of sandpaper.

In sanding irregular surfaces, the usual procedure is to tear the sandpaper sheet into four equal parts. Fold each part to get three separate surfaces. As one surface of the paper becomes dull, turn the paper over until the entire piece has been used. Hold the paper as shown in figure 3-54. This method of sanding is for surfaces for which a sanding block will not work. Avoid sanding too long in one spot. This could change the dimensions of a job.

After you have finished sanding with a folded sandpaper, finish sanding by tearing off a narrow strip of sandpaper. Use it shoeshine fashion. Use a fine grade of sandpaper when you are finishing small jobs. Use coarser grades on larger work.

The principal purpose of sanding a finished or lacquered surface is to remove any roughness that may be present without removing the finish. The pressure exerted on the sandpaper should never be greater than that necessary to get satisfactory results. Also, use as fine a grade of sandpaper as the job will permit.

Look at the finished surface to see if it is fully dry before trying to sand it. Select a sheet of sandpaper of proper grade for the job to be done. Sand the surface very lightly at first. Use strokes that are as long as possible. Do no more sanding than is necessary to produce a smooth surface. Also, examine the sandpaper often to see if any part has become gummed with finish material. If it has, do not use that part of the sandpaper any longer. It will scratch the surface of the job.

LATHE SANDING

Sanding work in a lathe should be done very carefully because the dimensions of the job may alter. Carefully turn the job to a smooth finish so only minor sanding is necessary to finish the surface. Use a fine grade of sandpaper (120 or 150) on the average-size job. Always remove the tool rest from the lathe before sanding a job.
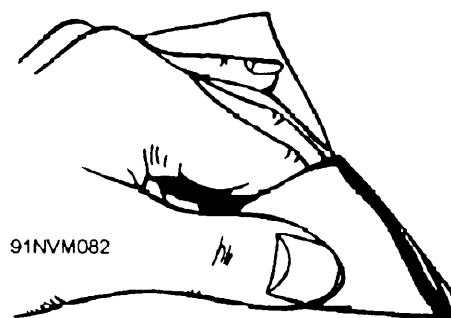
Figure 3-54.—Holding folded sandpaper.
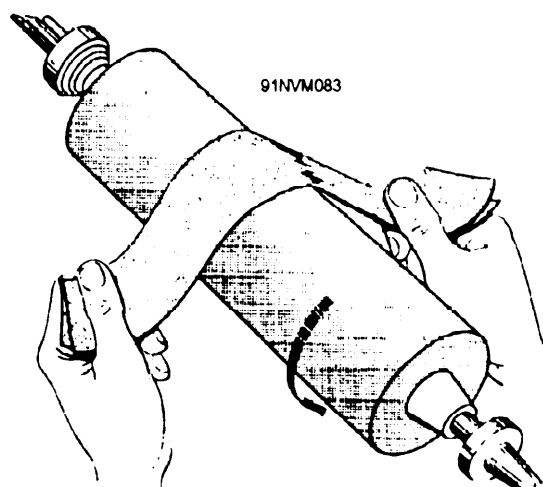
Figure 3-55.—Sanding a lathe job.

Figure 3-56.—Sanding at an angle.
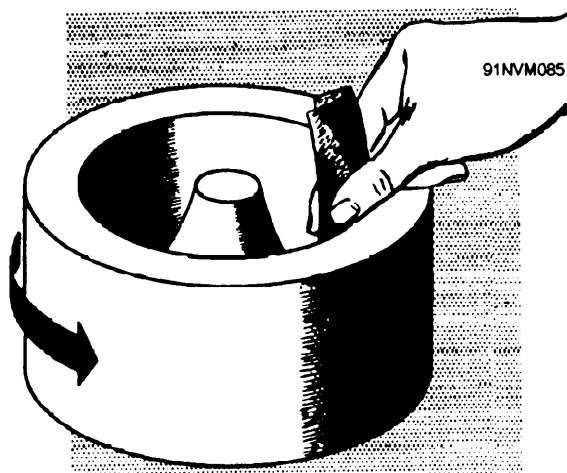
Figure 3-57.—Sanding a concave faceplate pattern.

If the job is small, use a half sheet. For a large job, use the whole sheet folded twice. Apply the sandpaper lightly (fig. 3-55), moving it along the surface of the job. **Do not sand in one spot.** When sanding the ends of the job, use a narrow strip of sandpaper.   Fold the sandpaper between your fingers in the shape of the sanding surface. Then hold it lightly against the stock. Rotate it at the proper angle so all angles, edges, or shoulders keep their designed shapes (fig. 3-56).

When sanding a concave faceplate pattern, you should start by tearing a suitable piece from a sheet of sandpaper. Fold it over twice. Bend the paper a few times to make it pliable. Then, sand the job as shown in figure 3-57. Do not knock off the sharp corners on the face of the bend.

Machine sanders are useful for smoothing stock and for putting draft on the sides of patterns. Be careful when operating a machine sander so you will not cut off too much stock and ruin your work.

SUMMARY

In this chapter, you have learned about the different types of wood, wood joints, cuts, and fasteners that HTs use in their jobs. But remember when tasked with a job, no matter how small, you should take the time to pick the right material for the job. A little extra time taken before you begin may save a lot of time later.

CHAPTER 4

BOAT REPAIR AND DECK COVERINGS

LEARNING OBJECTIVES

Upon completion of this chapter; you will be able to do the following:

● *Describe the techniques and materials used to repair small craft.*

● *Describe the applications of plastic boats and the procedures used to construct and repair plastic boats.*

● *Recognize the fundamental principles of metal boat repairs and discuss the safety equipment and procedures used.*

● *Describe the preliminary preparations to be made before laying deck coverings.*

● *Describe the application and installation procedures of tiles and nonskid surfaces.*

INTRODUCTION

As a Hull Maintenance Technician aboard ship and IMAs, you must be familiar with the procedures used in making repairs to small boats, because you will be called upon to make emergency and permanent repairs on wooden, metal, and plastic boats. Each boat repair job presents a unique problem, depending on the type of boat and the nature of the damage to be repaired. In doing any repair work, the goal is to make the boat as strong and seaworthy as possible. You may also be required to repair or even replace deck coverings. We will discuss the repairs of deck coverings later in this chapter. Right now, let us look at boat repairs. The material in this chapter consists chiefly of examples of small boat repairs and cannot be taken as step-by-step directions for repairing all types of damage to all boats.

Boat repairs vary and may include repairing structural members, removing and replacing damaged planking, caulking seams, making soft patches, and making plastic repairs.

The types of boats in current use by the Navy include fast patrol boats used for inshore and riverine warfare, landing craft carried for amphibious use, motor whaleboats, utility boats, and motor boats. Figures 4-1, 4-2, 4-3, 4-4, and 4-5 show some of the boats carried aboard ship. Since inflatable boats are covered in *Basic Military Requirements,* NAVED-TRA 12043, they will not be discussed in this text.

You will be able to make repairs more intelligently if you understand the general principles of boat construction. This information will help you learn the names of the parts of boats, boat fastenings, and other terms used by boat builders.

When the construction of a boat is authorized by NAVSEA, the boat is assigned a BOAT NUMBER. You will usually find the number cut on the inboard face of the keel, apron, or keelson.

The label plate is usually secured in a conspicuous location near the steering control station. This label contains the following information:

● Length and type of boat

● Boat registry number

● Maximum capacity (number of personnel)

● Builder (usually a boat building contractor)

● NAVSEA plan number (used for construction)

● Date completed
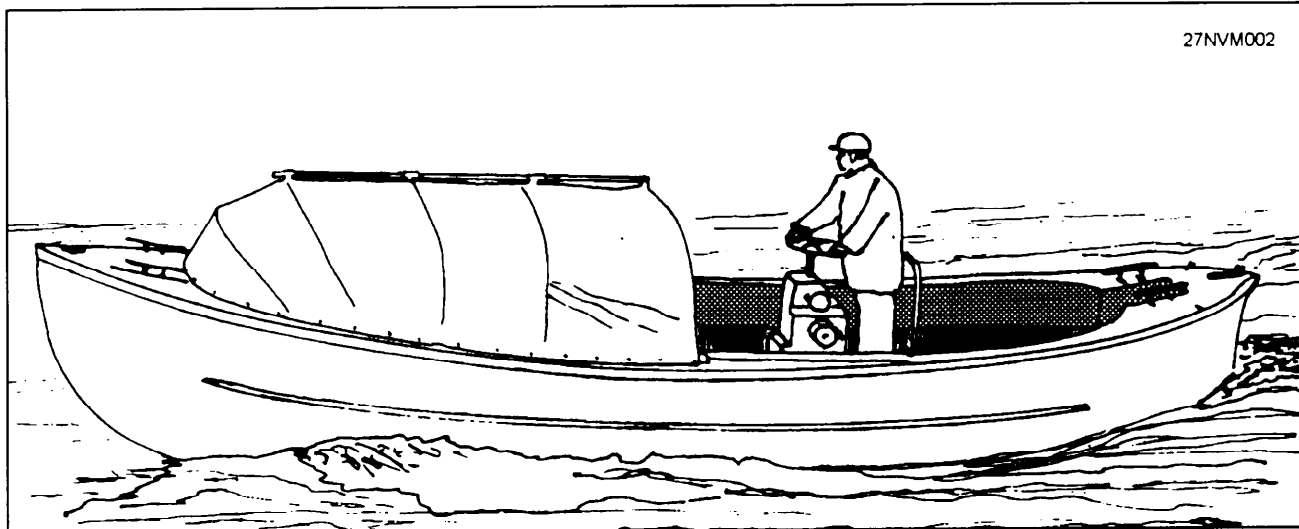
Figure 4-1.—A 26-foot Mk 10 motor whaleboat.
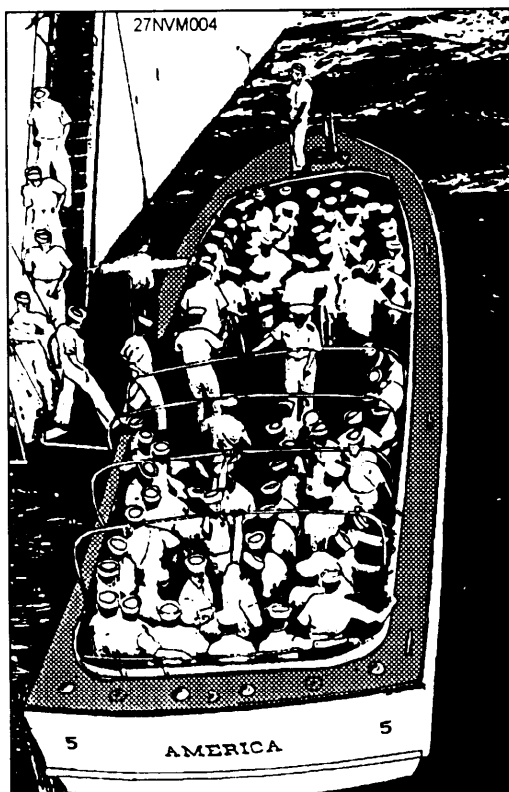
Figure 4-2.—Utility boat being used as a personnel carrier.

Figure 4-3.—A flag officer's barge.

INSPECTING BOAT DAMAGE

The first step in repairing a boat is to make a thorough inspection to determine the extent of the damage. It is particularly Important to determine the condition of the main strength members. A relatively slight amount of surface damage may be deceptive and may cause you to overlook deeper and more serious damage. For example, a direct blow that is heavy enough to damage the stem of a utility boat may cause severe damage to the stem apron, knee, keel, or keelson; a blow that ruptures the transom planking may break or crack a stern frame; and a broadside bump that seems to do little damage might actually loosen or damage an engine stringer or girder.

To determine the extent of the damage, you will probably have to scrape the paint away from a fairly large area. If the stem is damaged, you should remove the towing post and chafing plate. The towing post may be removed by pulling the retaining pin, which is located under the towing post partner, and lifting the post straight upward from the step or securing plate on the keel. Figure 4-6 shows a boat from which the towing post, or bitt, has been removed. On some craft, it may also be necessary to remove some of the decking to reach the stem and apron.
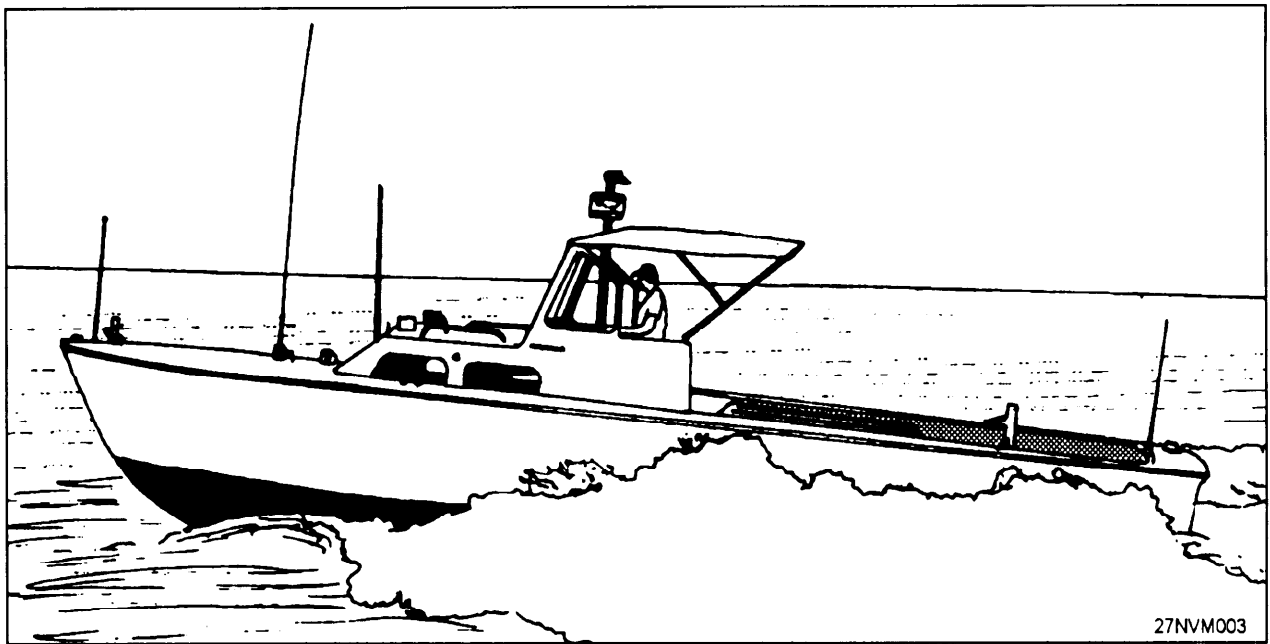
Figure 4-4.—A 36-foot Mk 11 LCPL.
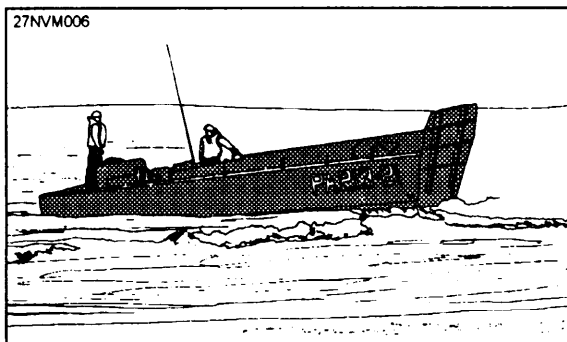
Figure 4-5.—LCVPs hitting the beach.

Figure 4-6.—Looking forward on a boat with the towing post removed.

WOODEN BOATS

Almost all of the operational Navy small craft are now built of glass-reinforced plastic. The wooden boats that you may have occasion to repair will be odd types, kept for recreational or historic purposes. The information in this section will help you make temporary repairs to these wooden boats. They may then be operated until permanent repairs can be performed by technicians assigned to ships or shore commands with the necessary facilities and skilled ratings.

There are three causes of damage to wooden boats. The most difficult damage to repair is caused by rot. The other forms of damage are the result of fire or physical forces such as collision, grounding, broaching, or other evidences of poor seamanship.

There is little a Hull Maintenance Technician can do to prevent physical damage to a boat.

DECAY

Preventing rot or decay requires joint efforts with the Boatswain's Mates or other personnel who are charged with painting and caulking the boat. You should inspect boats in your charge fairly often to check the following causes of decay:

— Parts of the boat may be too dry or too wet. Strong sunlight or storage near hot machinery can dry out the wood. Dryness causes wood to shrink and crack. Water can then seep between planks and into cracks, wetting interior areas which will not dry before rotting has started. The microorganisms that cause wood to rot require a limited range of dampness to be active. Most of these organisms are fungi, and they will develop in wood having over 30 percent moisture content. They need some air, and they will not develop in wood fully saturated with water, from which comes the term *dry rot.* Once in wood, they will be dormant if the moisture content is less than 20 percent, or if the wood is saturated. Fresh water causes more decay than salt water, so inspect areas where rainwater or condensation may be trapped. Boats with closed spaces should have adequate ventilators installed or hatches opened up and interiors dried out whenever the weather permits.

— Cracks and seams are places where decay can start. Not only can dampness persist in narrow cracks, but other agents that cause decay can get in there. Look for cracks in boards and faulty caulking. If you find any, notify the boatswain's personnel to correct the problem.

— Plain iron fasteners or galvanized fittings that have lost their zinc coating will favor decay in oak frame members. Also, water may leak into the hull in the vicinity of these fasteners.

— Caustic chemicals, such as those used in cleaning, should not be allowed to stand in contact with wood. They can dissolve the wood and weaken it. Acids are less destructive; but strong acids, such as those used in batteries, will attack wood.

— A common cause of decay is destructive attacks by marine borers. This and general marine fouling are prevented by proper bottom paints and occasional overhaul. Borers are not a problem for boats kept out of the water.

Decay, particularly rot, will not start in any place where it is easy to detect. It may cause cracks and discoloration of paint, but since it is most likely to occur in bilges, behind ribs or frames, or in closed comers, it will be hard to see. Traditionally, it is found by probing with the point of a knife, chisel, or screwdriver. Press the tip of the instrument against the wood. If the wood is sound, the point will encounter increasing resistance as it penetrates deeper. In rotten wood, the resistance will seem to decrease once the paint layer is penetrated. A screwdriver tip will seem to pop through the paint and into rotten wood.

Decay may also be found in association with physical damage. Weak planks and timber will be the first to yield to stress. When inspecting collision or similar damage, look also for signs of rot.

EMERGENCY REPAIRS

Emergency repairs to boat planking can be made with sheet lead, plywood, canvas, or glass-reinforced plastic. If the patch is anchored to sound wood, it can last several weeks. If an emergency patch just covers a hole and is fastened to rot-affected wood, it should be replaced as soon as possible.

Most emergency repairs to frame members consist of reinforcing damaged timbers by backing them up and shoring them. Backup bracing can be temporarily nailed or lashed in place. Boats having serious structural damage are not seaworthy, and temporary repairs are made only to get them to a safe place where they can be repaired or surveyed.

REPAIR PROCEDURES

The first step in repairing a damaged boat is to make a general survey of the situation. Determine as best you can the extent of the damage. Having done this, consider whether you have the facilities and materials to make a repair. If work and storage space are limited, you might have to defer work on the boat until materials can be obtained. If you have adequate space, it would be best to haul out the boat for a detailed inspection and drying out before work is begun. If the boat has been sunk, the Enginemen will want to take out the engine, transmission, and electrical equipment for drying out and overhauling. If the hull is not repairable, remove the reusable parts and dispose of the hull.

As soon as a boat has been hauled out, its bottom should be cleaned. Barnacles and other marine growth are more easily removed when they are wet. They smell better then too. After the bottom is cleaned, the boat can be set up in the work area. The hull should be dried out, the bilges cleaned, and any rotten wood cut out so adjacent areas can dry out. When the boat has

been cleaned and dried, you should make a careful inspection to determine the extent of damage.

Physical damage may extend far from the obviously stove-in areas. A boat may have been squeezed in a collision situation, and although there is obvious damage on one side, equal stresses have been suffered on the other side. By calculating the direction that forces were exerted on the hull, you can estimate the points where stresses were transmitted. Look in those areas for loosened fastenings or cracks in the wood.

If decay is present, either as the cause of failure or incidental to it, you must plan to remove not only the rotted wood, but also the wood into which the decay organisms are assumed to have spread. The rule in doing this is to remove sound wood for 2 feet along the grain from the soft wood and for 2 inches across the grain from the soft wood. Plywood should be removed for a 2-foot radius from the rotten area. If this is not done, decay can spread back into the repaired area.

When you remove a damaged plank, plan to take out a generous length. The new plank should butt to the end of the old one between frames, using a butt block; you should saw the ends to meet that requirement. If the plank is fastened with screws, chisel away the putty or the bung plugs and remove the screws. If boat nails are used, cut off the heads with a cold chisel. When the plank is pulled off, either pull the nail or drive it into the frame. To remove rivets, cut off the upset head and punch them out. (Rivets are usually found in lap stroke hulls, which are best sent to an expert for repair.) If the plank is fastened with drifts, pry them out by leverage on the plank, or allow the plank to break at the rib, then pull the drift or drive it flush.

To repair a sprung frame or rib where the exterior planking is sound, construct a sister frame and fasten it along the old frame. The sister frame should extend well to either side of the damaged area. Planks may be refastened to the sister frame.

If a frame has rotted, or is badly damaged, it must be replaced. To replace a curved frame section, it is easiest and best to laminate the replacement part on a template; or, if the exterior of the boat is sound, the section could be built up in place. On Vee hulls, the lower ribs should go from keel to chine, and the side ribs from the chine to the sheer strake. The ends should be joined as were the original members. Curved rib sections can be joined to the ends of the old rib if

necessary. All frame member sections should be joined with a scarf joint if at all possible. A scarf with a 12:1 pitch is best. A scarf with this pitch, glued with epoxy and secured by boat nails, bolts, or rivets, will be nearly as strong as the original member. If you use epoxy glue, you can allow some gap in the joint since epoxy has better strength in tension than regular marine glues. A good scarf can be made by overlapping the members to be joined and shaping both ends with one cut of a saw at a steep angle. Heavy timbers must be sawed and carefully planed to shape. When a rib or strake cannot be easily reached, the scarf angle will probably have to be chiseled into it. The end of the new section then is carefully fitted to this angle. Since epoxy has strength in tension, rougher faces of joints can be used than was possible with older glues.

The easiest way to lay out a replacement part is to use the old part as a template. If the old part is too badly damaged, you may be able to construct a template of scrap materials or lay out the new part by careful measurements. Experienced boatwrights have a number of techniques to form duplicate replacement parts, but for emergency repairs you can probably settle for any method that will fill the hole or provide adequate reinforcement. Plastic patch materials permit simple, quick repairs that formerly were not possible.

FERROCEMENT BOATS

Ferrocement is a material finding increased use as a low-cost material for hull construction. It is a combination of steel-reinforced mesh and portland cement binding. The reinforcement material ranges from several layers of chicken wire to a few layers of specially woven steel wire. Ferrocement hulls may also have some structural steel or steel pipe reinforcement or framing.

Repairable damage to ferrocement hulls probably will be in the form of punctures or structural damage from collisions or groundings. Other failure of these hulls will be caused by poor design, materials, or workmanship. Hull failure from these causes is not economically repairable since the seaworthiness of the entire craft is questionable.

To repair punctured areas not over about 1 foot in greatest diameter, use the plastic patching kit and basically the same techniques described later in this chapter for repairing fiberglass hulls.

Damaged ferrocement can be cut away with a masonry blade in a portable circular saw. The edges of the hole can then be scarfed with a heavy duty sander, but not to the degree of taper possible with fiberglass. Additional reinforcement can be added to the rear of the patch. Epoxies bond very well to ferrocement.

Larger damage may require some structural reinforcement. Structural steel members may be repaired by welding, and steel backing to repaired areas can be welded to structural members. Welding heat will decompose some of the surrounding cement, which should be chipped away and replaced with epoxy.

To bolt repair patches to ferrocement, use plain black iron carriage and stove bolts. Galvanized hardware does not stand up well in ferrocement.

PLASTIC BOATS

Some types of damage to plastic boats require slight deviations from the standard repair procedures, but personnel who can effectively repair a hole in the hull should have little or no trouble with other plastic repairs.

USES AND IDENTIFICATION OF PLASTICS

Plastics in naval construction have become increasingly important. Plastic patching has become standard practice aboard most ships in the Navy.

Plastics can be identified by their chemical and physical properties. For repair purposes, the most important plastic categories are the cellulose products, the protein plastics, and the synthetic resins. Physically, plastics may be divided into two basic groups: THERMOSETTING materials and THERMOPLASTIC materials. A thermosetting plastic has no melting point. Although a thermosetting material can flow and be molded, it will neither soften when heated nor return to its original liquid state. A thermoplastic material, however, will soften when heated. To illustrate, let us compare these two kinds of plastics with steel and concrete. Steel can be heated and formed, and when reheated, will soften; a thermoplastic material is like that. On the other hand, once concrete has set, it cannot be reformed; this is characteristic of a thermosetting plastic.

Polyester thermosetting resins, known as polyesters, are extensively used by the Navy. By adding various activators (catalysts and accelerators) in small quantities to the liquid polyesters, chemical reactions occur that cause the material to become rigid. This process of changing from one state to another is called curing. By varying the percentage of catalyst added, the resin can be made to cure in periods ranging from 30 minutes to over 24 hours.

REPAIRING PLASTIC BOATS

Although the use of plastics in naval construction and repair is relatively new, plastic materials and boats have become important for naval use.

The factors in favor of the plastic boat are many; it has a monolithic structure (can be cast in one piece), it can be mass produced, and it can readily be maintained and repaired. Ships are supplied with metallic pipe and general-purpose repair kits. These pipes and kits are used for emergency repairs of battle damage to piping for water, oil, gasoline, and refrigeration lines. Materials and instruction are provided not only for repairing pipes, but also for repairing damaged glass-reinforced plastic structures such as boats, floats, deck cabins, and hull and deck coverings.

Repair Kits

The metallic pipe and general-purpose repair kit are repair locker equipage. The repair kits are not to be removed from the repair lockers except in the case of an emergency and with the authorization from the leading HT or the damage control assistant (DCA), or when the shelf life date has expired and a new kit has been placed in the locker. The shelf life of a kit is 2 years. When a kit is removed from the locker because it is past its shelf life, the HT shop may keep the kit for boat repairs and training purposes. The repair kit contains epoxy resin, hardener, and glass reinforcement in the form of mats or woven cloth. Auxiliary materials include separating film, kraft paper, protective gloves, wooden spatulas, resin spreading tools, brushes, and repair instructions. Sufficient quantities of these materials are provided in a standard kit to replace about 400 square inches of damaged 1/4-inch laminate, and tubes of paste resin are provided for repairing minor surface imperfections.

The kit supplier has preweighed and packaged the resin and hardener in the proper proportions. The resin cans are only slack filled to allow the hardener to be added to the can of resin when the two are mixed.

Proper storage of plastic repair kits is important. They should be stored in a cool, dry place. Temperatures should be kept below 70°F and the relative humidity should be less than 50 percent. Kits should never be stored in temperatures below 32°F. Storage life of the resin will vary; however, under these specified storage conditions, the resin should remain stable and usable for an indefinite period of time.

Any chemicals or solvents should be handled with caution. The repair of reinforced plastics is no exception. Cutting and grinding of reinforced plastic laminates generates a fine dust that irritates the skin and eyes. Inhalation of the dust should be avoided.

The following safety precautions should be followed:

1. Wear protective gloves, goggles, and respirators provided with the kit. If available, apply a protective hand cream to all exposed skin areas.

2. Avoid contact with the eyes, skin, or clothing. If these materials contact the skin or eyes, immediately flush them with water for 15 minutes. If the eyes are involved, obtain medical attention.

3. When working in confined spaces, be sure there is adequate ventilation. Where such ventilation cannot be provided, organic respirators are required for protection against fumes.

4. If clothing becomes contaminated, remove it and wash it thoroughly before reuse.

5. Always wash exposed skin areas thoroughly when you are finished working.

6. Keep chemical containers clearly labeled and tightly covered when they are not in use. When mixing a polyester resin, NEVER mix the catalyst and accelerator directly together or an explosion may result. Always mix chemicals according to instructions.

7. Do not smoke or work near hot surfaces or open flames while using these materials.

Basic Considerations

Many factors determine how closely the strength of a reinforced plastic repair will resemble the strength of the original laminate. Workmanship, repair techniques, the glass reinforcement, and resin all play an important part in any repair. Reinforced plastics are easy to repair if you have a knowledge of materials used and proper repair techniques.

Three types of reinforcement are most frequently used—singly or in combination—in glass-reinforced plastic laminates. The cheapest and weaker type, random glass mat, consists of chopped glass fibers that are either lightly bonded together with a small amount of binder resin, or mechanically stitched into a random, jackstraw arrangement. These mats may be obtained in weights from 1/2 ounce to 3 ounces per square foot. The strongest and most expensive type is woven glass cloth. It is available in a wide range of weaves and styles, varying from a coarse, loosely woven fabric to a fine,

closely woven one. Woven fabrics are usually identified by a style number that refers to a specific cloth or a certain weave, weight, and thickness. For example, style #1000 cloth identifies a plain weave cloth that weighs 10 ounces per square yard and is 0.013-inch thick. Woven fabrics are coated with a finish to improve the bond between the glass and the resin. The third type of glass reinforcement, which is gaining popularity because it is cheaper than cloth and builds up the thickness of a laminate faster, is called woven roving. This type of reinforcement resembles a hand-woven potholder both in weave and appearance. A commonly used type of roving is about 0.040-inch thick and weighs 24 ounces per square yard. Of the three types of reinforcements, the woven fabric is the easiest to handle and the most dependable for repair work.

Two types of resins are usually used for repairing reinforced plastics. The first is a polyester, which may be obtained in a wide range of viscosities. The consistency of the very high-viscosity resin resembles heavy molasses, while that of the low-viscosity resin is like water. Usually, the low-viscosity resin will saturate or "wet-out" a glass reinforcement faster, but it will also drain more rapidly on a vertical surface. This drainage may be undesirable in some applications and may be minimized by the addition of a small amount of a finely divided silica. A highly viscous resin may be thinned by the use of a small amount of styrene. Many resins are available commercially that have been specially compounded to the proper viscosity for repair use.

Polyesters are also extremely versatile in cure (hardening) characteristics. The addition of a small amount of an organic peroxide catalyst in a powder, paste, or liquid form, and an accelerator will cause a cure to occur at ambient temperatures above 50°F without the application of heat. The working life (time within which the resin remains liquid and usable) and cure time may be varied by adjusting the proportions of the catalyst and accelerator used. The resin supplier will generally provide information on resin formulations. Some resins are supplied with the accelerator already added, thus only the addition of the catalyst is required. Temperature greatly affects the cure time of polyesters; the higher the temperature, the faster they will cure. Polyesters also have a limited storage life of about 6 months to a year. Standing in storage causes them to gradually thicken until they become unusable even though the catalyst has not been added.

Epoxy, the second type of resin that may be used in reinforced plastics repair at room temperature, is widely recognized as an adhesive for a great variety

of materials. Although better adhesive properties are generally claimed for epoxies, especially when heat is applied to achieve a higher strength bond, they are more costly than polyesters. Like the polyesters, epoxies are available in a variety of viscosities and with a wide range of other characteristics.

Epoxy resins are activated for room temperature cures by the addition of a recommended amount of a specific room temperature hardener. However, unlike the polyesters, the proportions of hardener should not be varied to change the cure time, since any change in concentration will adversely affect the other properties. Cure conditions can be varied only by changing hardeners or by cooling or heating the resin. There are many types of room temperature hardeners from which to choose. Users are cautioned that room temperature hardeners are alkaline in nature, so they should be handled with care. Rubber gloves and eye protection are recommended when you are handling epoxy resin and hardener. Always wash the skin immediately after any contact with the hardener.

Repair Procedures

The three types of repair patches applied to reinforced plastic laminate are shown in figure 4-7.
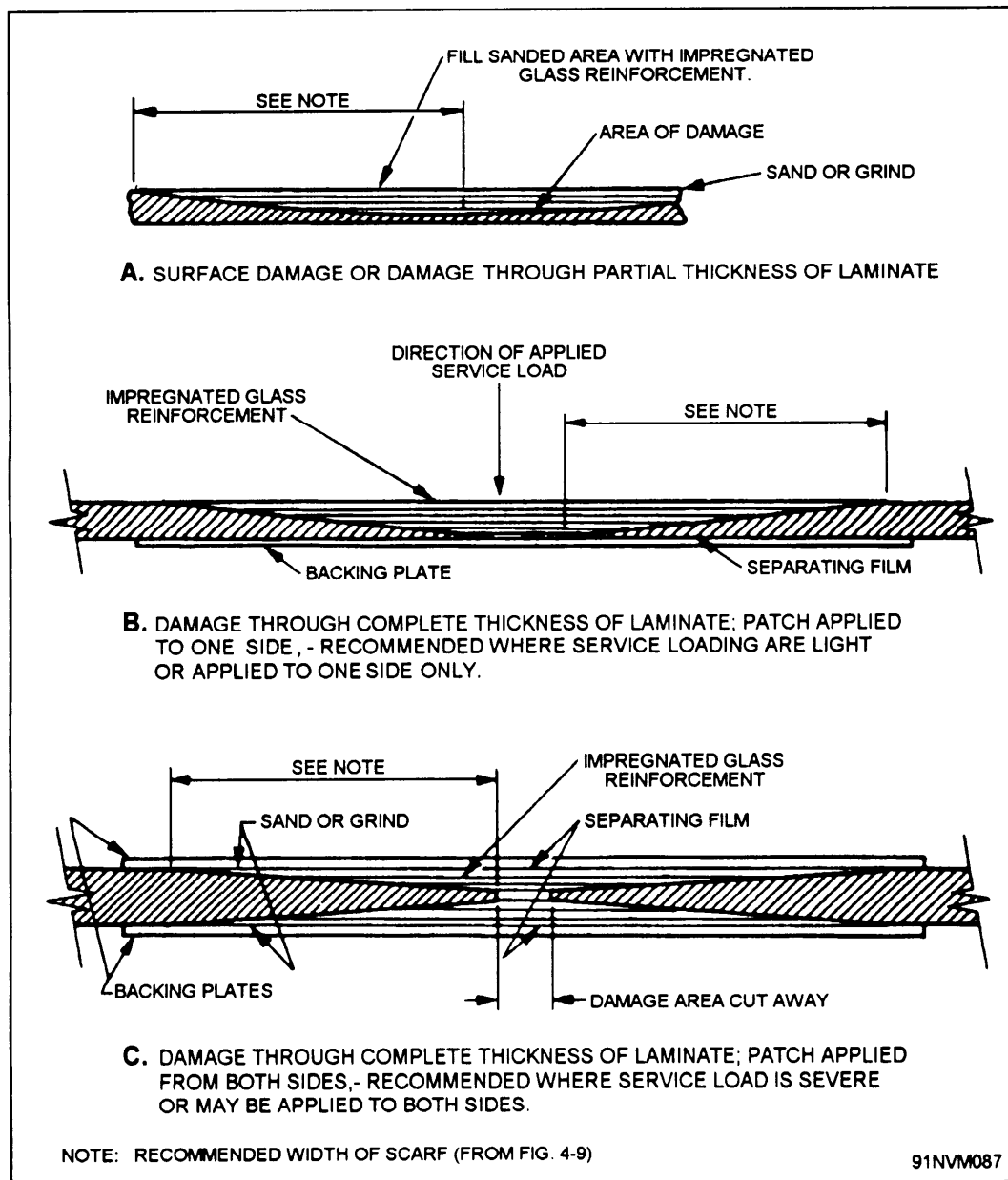
Figure 4-7.—Types of patches applied to reinforced plastic boats.

4-8

They are the surface patch, the one-sided patch, and the two-sided patch.

The basic steps are (1) planning the repair, (2) preparing the damaged area, (3) tailoring the reinforcement material, (4) preparing the resin system, (5) impregnating the reinforcement with resin, (6) applying the patch, (7) curing (hardening) the patch, and (8) finishing.

PLANNING THE REPAIR.—Before beginning the repair, several details should be checked and advance plans made to avoid later problems. If the repair is to be accomplished in an unsheltered area, check the weather. If it is cold (below 50°F), rainy, or blustery, wait for a better day or move to some indoors area away from the elements. If it is a bright, sunny day, be sure that the area is well shaded.

Assemble the necessary equipment, in the quantities required, at the repair site. This includes the materials provided in the plastic repair kit plus the following supplementary items:

- Chalk for marking the area to be repaired

- Protective equipment, such as goggles and respirator

- Ruler

- Saw (metal-cutting handsaw, holesaw, or reciprocating saw) for cutting away the damaged area

- Disk sander, cone sander, or file for grinding away the damaged portion and scarfing (beveling edge of cutout area)

- Cardboard, sheet metal, or plywood panel for use as backing and cover plates

- Tape, shoring, or bracing for attaching or supporting the backing and cover plates

- Acetone for cleaning the surface and the equipment

In determining the quantities of materials required for the repair, outline the area to be cut away and mark the area to be scarfed (beveled) with chalk (fig. 4-8). The recommended width of the scarf for
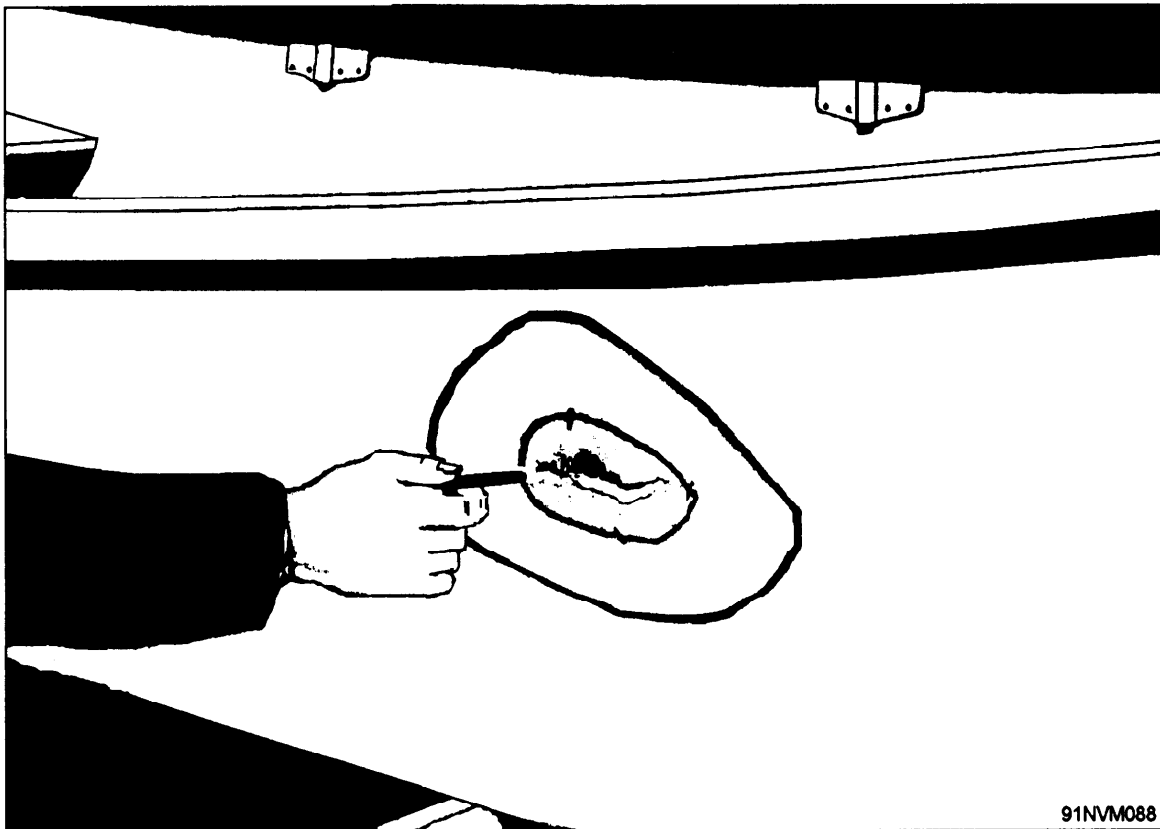
Figure 4-8.—Oval-shaped chalk marks delineate the area to be cut away (inside chalk marks) and the area to be scarfed (outside chalk mark to inside).

laminates up to three-fourths of an inch thick can be obtained from figure 4-9.

Round or oval-shaped repairs are preferable to ensure that you get a better bond and less chance of cracks in the base material. You should never use rectangular cuts with sharp comers. To estimate the amount of resin and glass reinforcement required for a round patch, determine the thickness of the laminate and the average diameter. For a rectangular or oval patch (fig. 4-10), the average area must be estimated.

Turn to the nomogram (fig. 4-9) to obtain an estimate of the materials required. Draw a straight line between scale A (average diameter and/or average area) on the left side and scale B (thickness) on the right side. Where this line intersects scale C, read the approximate amounts of cloth and resin required. Note that the estimate exceeds the actual requirement by 30 to 40 percent, particularly with respect to cloth, to allow for wastage. Select from the kit the number and size of cans of resins and hardener required. To avoid waste, open and mix the cans as they are needed.
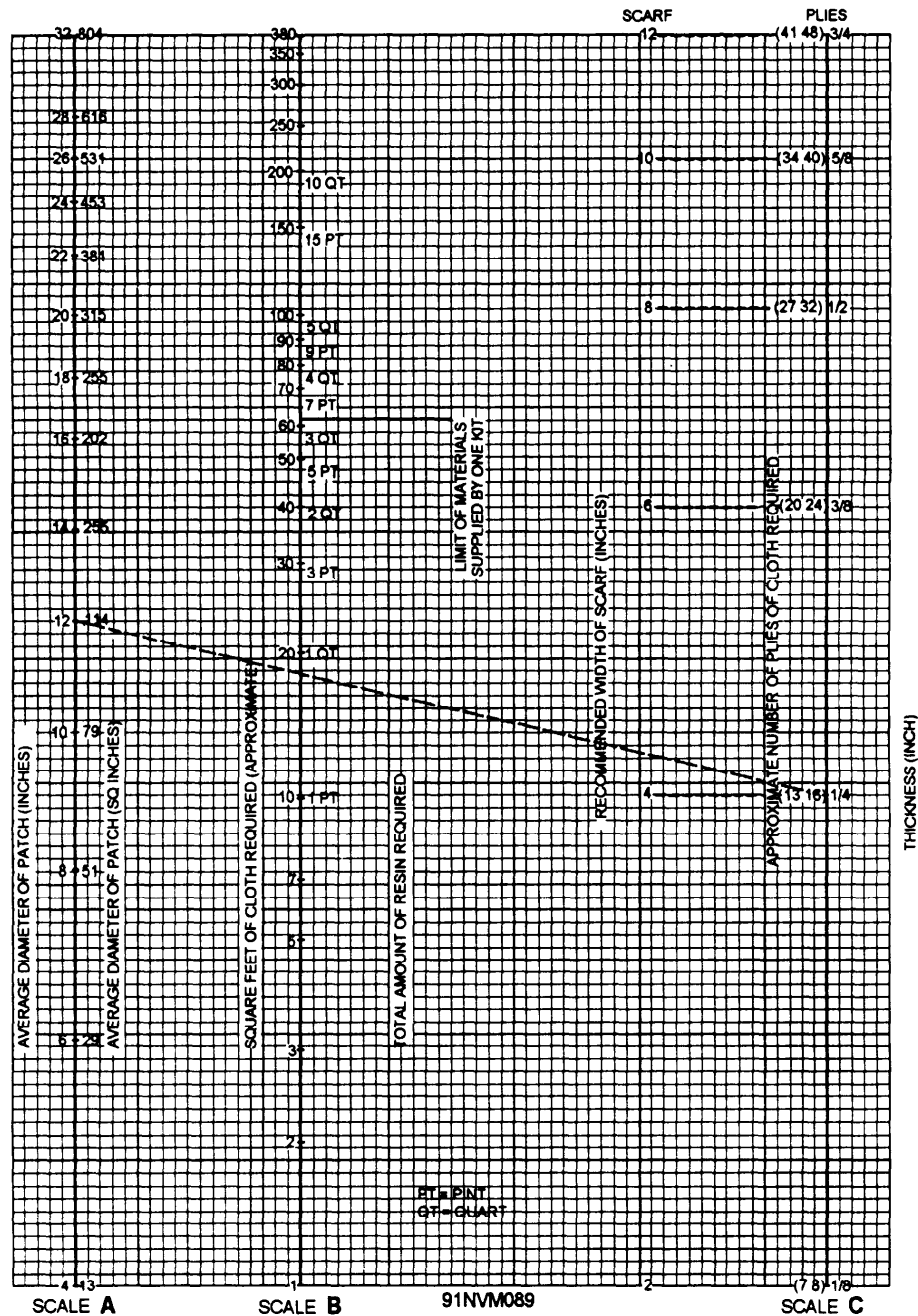
Figure 4-9.—Estimating materials.

CIRCULAR PATCH

AVERAGE DIAMETER

DIAMETER OF HOLE

AVERAGE AREA (.785 X AV. DIA.²)

½ WIDTH OF SCARF

½ WIDTH OF SCARF

½ WIDTH OF SCARF

LAMINATE THICKNESS

RECTANGULAR PATCH

½ WIDTH OF SCARF

AVERAGE AREA (A X B)

HOLE

½ WIDTH OF SCARF

½ WIDTH OF SCARF

WIDTH OF SCARF

LAMINATE THICKNESS

91NVM090
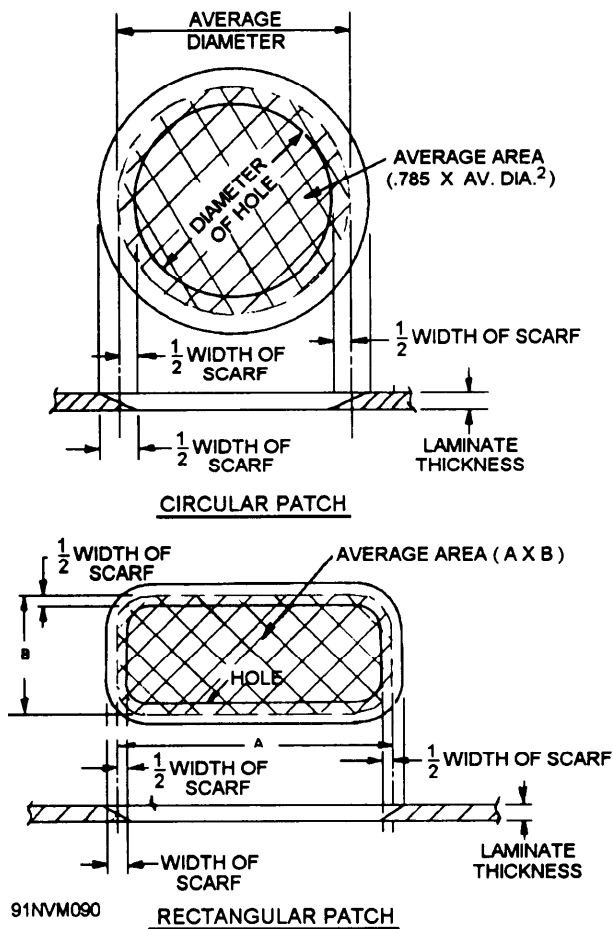
Figure 4-10.—Average diameter and area of a patch.

Scale B also indicates the recommended width of the scarf and the approximate number of plies of cloth required for any given thickness. The number of plies required is affected by the variation in the thickness of the cloth, the viscosity of the resin used (the thicker the resin, the fewer the plies), and workmanship. The amount of cloth specified on scale C is based on the maximum number of plies that might be used, and the resin estimate is based upon an approximate resin content of 60 percent.

To illustrate the use of the nomogram, assume that a repair is to be made to an 8-inch diameter hole in a 1/4-inch thick laminate. Looking at scale B, the recommended width of the scarf is 4 inches, and the approximate number of plies of style #1000 glass cloth is 13 to 16. The average diameter will be 8 inches + 4 inches (fig. 4-9) = 12 inches. Drawing a line between 12 inches on scale A and 1/4 inch on scale B (see dotted line in fig. 4-9), approximately 18 square feet of style #1000 glass cloth and 1 quart of resin are required. (As mentioned previously, the materials estimate may be 30 to 40 percent in excess of the actual requirement.)

PREPARING THE DAMAGED AREA.—The next step is to prepare the damaged area. This is accomplished in one of two ways. If the damage extends only partially through the laminate, merely grind the damaged area down to the sound laminate with a disk or cone sander using a coarse abrasive. If the break is all the way through the laminate, however, the damaged area should be cut out on the first chalk mark nearest the damage with a metal cutting handsaw or reciprocating sabre saw (fig. 4-11). Then, scarf back

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Figure 4-11.—Damaged area being cut away.

to the second chalk mark (fig. 4-12). This increases the area to which the patch will adhere so that a stronger bond may be obtained. The roughened surface caused by the coarse abrasive provides a better bond between the old surface and the patch. After the grinding has been completed, wipe away all the sanding dust and clean the entire adjacent area with acetone or lacquer thinner.

The procedure just described is for preparing a damaged area for the application of a patch on one side. The patch will generally be placed on the readily accessible external surface, because it provides greater resistance to external stresses. However, in instances where maximum strength is necessary in both directions, and both sides are readily accessible, it may be desirable to make a patch on both sides (view C of fig. 4-7). Both sides are prepared in the same manner as a repair to one side. Then, the patch must be made on both sides. Repairs of this type are especially desirable for thick laminates (three-eighths of an inch and over). Apply the temporary backing plate to support the patch while it is curing (hardening). For small repairs on flat surfaces, the backing plate can be a piece of heavy cardboard, plywood, or sheet metal. For curved areas, a formed piece of aluminum or steel sheet metal is generally preferred.

When accomplishing a repair on a vertical surface, use a plate on each side of the patch to hold the patch in place while it is curing. Cover these plates with separating film so that they may be removed easily later. Hold the plates in place by taping, shoring, or bracing them with lumber (fig. 4-13).

If the underside of the damaged area is inaccessible, apply a resin-wetted backup patch about 2 inches larger than the hole into the scarfed area on the exposed side. This patch should be allowed to cure (harden) to form a foundation for the patching material. After the backup patch has hardened, lightly sand the surface to provide a better bond between it and the material to be added later.

TAILORING THE REINFORCEMENT MATERIAL.—To cut the glass reinforcement to fit the repair, prepare paper templates for the innermost ply that are slightly larger than the hole, and for the outermost ply to barely overlap the scarfed area. Each of the intermediate plies should be cut proportionally larger than the preceding smaller ply. (See fig. 4-9 for the approximate number of plies required for a given thickness.) If the patch is being made from both sides, two sets of plies should be tailored as described, one for each side.

Figure 4-12.—Scarfing operation.

4-12
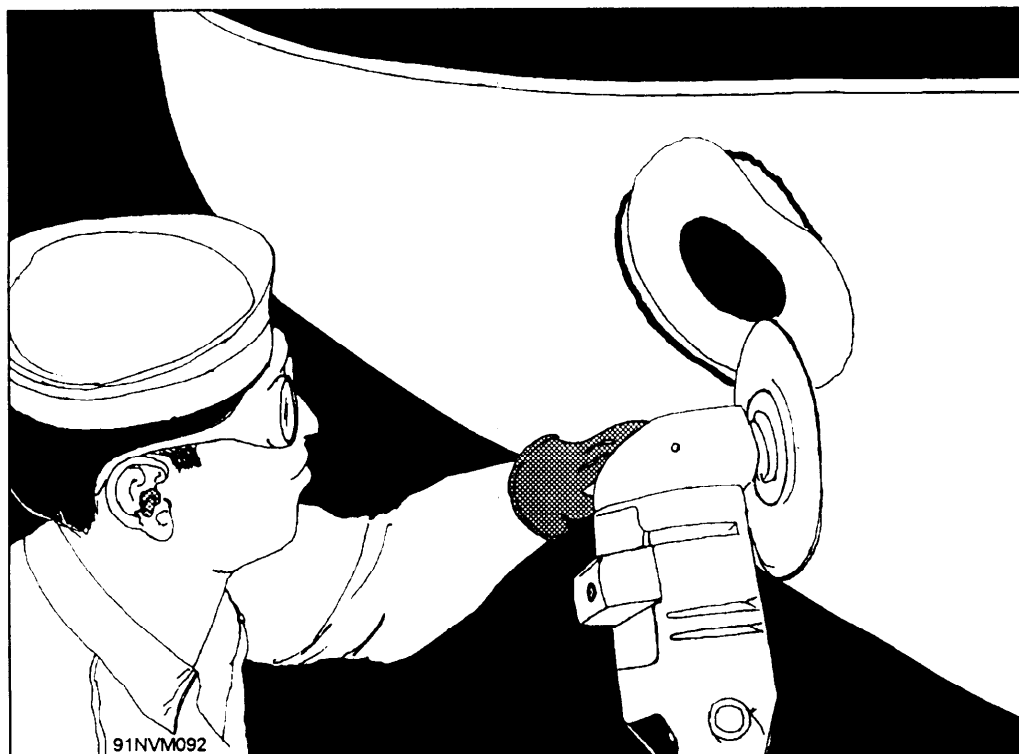
Figure 4-13.—Placing shoring over a film-covered backing plate.

Keep all glass reinforcements clean and dry. They should not be handled with dirty or greasy hands. Cut and handle the reinforcement carefully since the cut edges of some reinforcements unravel easily if handled carelessly. Glass cloth should be used for most general repairs, especially where strength is important. The glass mat may be used in fillets or for thicker buildups. alone or in combination with glass cloth.

PREPARING THE RESIN SYSTEM.—The resin and hardener in the repair kit has been preweighed and packaged in the proper proportions for mixing. If the temperature is much above 70°F, bring the resin temperature down to about 70°F, as higher temperatures will shorten the working life of the resin. Conversely, if the temperature is low, it is advisable to keep the resin indoors until used. Prior to opening the containers, clean and dry them thoroughly so that no moisture or foreign matter will get into them. NEVER mix the hardener with the resin until the preceding steps have been accomplished. The amount of resin needed for the patch may be estimated from figure 4-9.

Be sure to mix the entire contents of the hardener container thoroughly with the resin. Once the resin formulation has been thoroughly mixed, the "die is cast." Work ahead steadily to complete the repair within the working life of the resin. The resin system in the kit has a relatively short working life that depends primarily on temperature conditions.

IMPREGNATING THE MATERIAL AND APPLYING THE PATCH.—There are two methods for preparing the reinforcement material with resin for applying the patch: method one, which is particularly desirable for use with the vertical patch; and method two, which is desirable for use on horizontal surfaces where impregnated plies can be laid in place one at a time. In both methods, the first step is to brush a coat of mixed resin formulation over the area to be repaired.

Method One.—On a flat surface lay a piece of separating film larger than the largest tailored ply of reinforcement. Center the largest ply of glass cloth on the separating film and saturate it with resin mix by brushing or by pouring and spreading the mix with a wooden spatula from the repair kit. Center the second tailored ply over the first ply, then impregnate it with resin. Continue this procedure, saturating each successive smaller ply thoroughly, until all tailored plies of reinforcement are finished, with the smallest ply on top. Apportion the resin so that there is enough to uniformly saturate all plies. Then cover the saturated reinforcement with another sheet of separating film and work the air bubbles out by squeezing the wet reinforcement from the center outward with a clean spatula or spreader from the kit. Keep a close check that the time does not exceed the

4-13

working life of the resin. After most of the air and excess resin have been removed, it may be desirable to apply another coat of the remaining resin to the repair area to assure that there is sufficient bonding resin.

Next, carefully feed the top layer of separating film adjacent to the smallest ply from the patch; then lift and center the patch over the hole with the separating film on the outside (fig. 4-14). This film should not be removed. With this film in place, once again work out any entrapped air and excess resin using a roller or wooden spatula. This also causes the patch to make intimate contact with the scarfed area. When the patch is being made on a vertical surface, apply a cover plate by taping, clamping, or bracing, to hold the patch firmly in place during the time needed for hardening or curing.

Method Two.—When using this procedure, you will lay individual plies of glass directly in place. One advantage this method has over method one, is that plies or reinforcements may be omitted or added in the event the calculated number of plies does not give the correct thickness buildup. A very liberal coating of resin must first be applied to the repair area. Then place the smallest ply of reinforcement in the hole and saturate it with resin. Add successively larger plies. Apply sufficient resin to each ply so that it will squeeze through the next ply, pushing out the entrapped air. Place a clean sheet of separating film over the top ply and work out the excess air and resin from the center to the edge of the patch. A cover plate may be used.

If the patch is being applied to both sides, follow the method being used for each side separately. The length of scarf and the amount of materials estimated for the repair on each side should be based on one-half of the total thickness of the laminate. Apply the patch to one side; then after it has cured, lightly sand the opposite side and apply the second patch to that side. In some applications, a patch can be applied to both sides in succession (before the first patch cures); however, this procedure requires care and skill.

CURING.—The patch should remain undisturbed at least overnight. Heat lamps may be used to speed the cure (fig. 4-15); but in using, you should not overheat the patched area as the cure reaction may "run away," causing frothing, blisters, and porosity. Lamps should be kept at least 1 1/2 feet away. You should wait a couple of hours to permit the resin to set at room temperature and then give it a final "kick" with heat.

FINISHING.—After 12 to 24 hours, the patch is ready for finishing. The time required will be less than
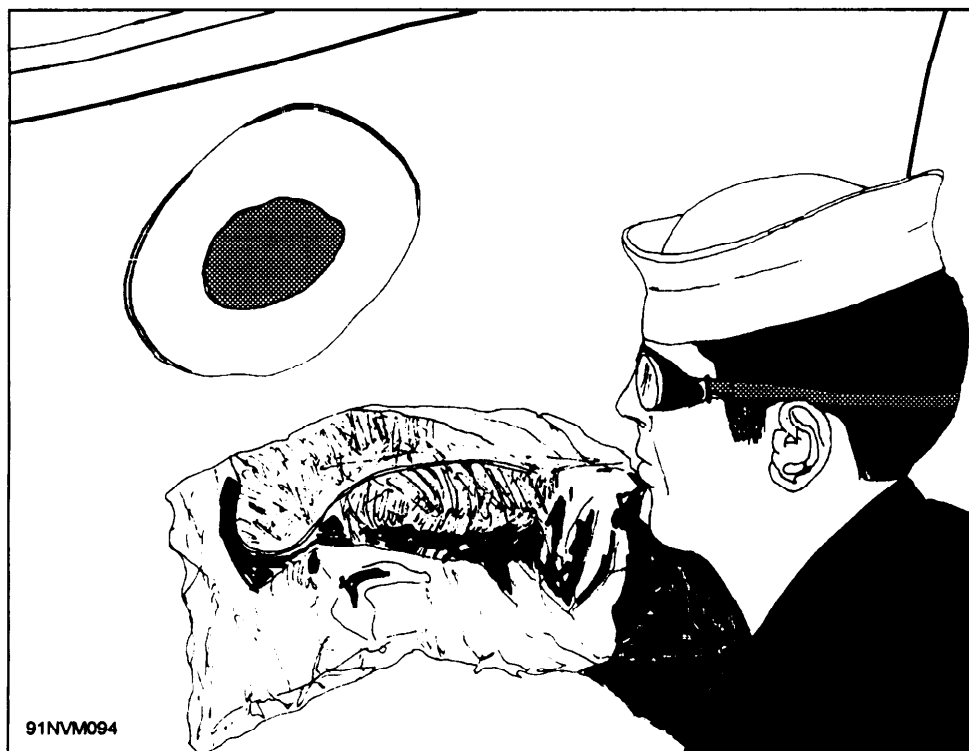
Figure 4-14.—Entire patch being put in place.
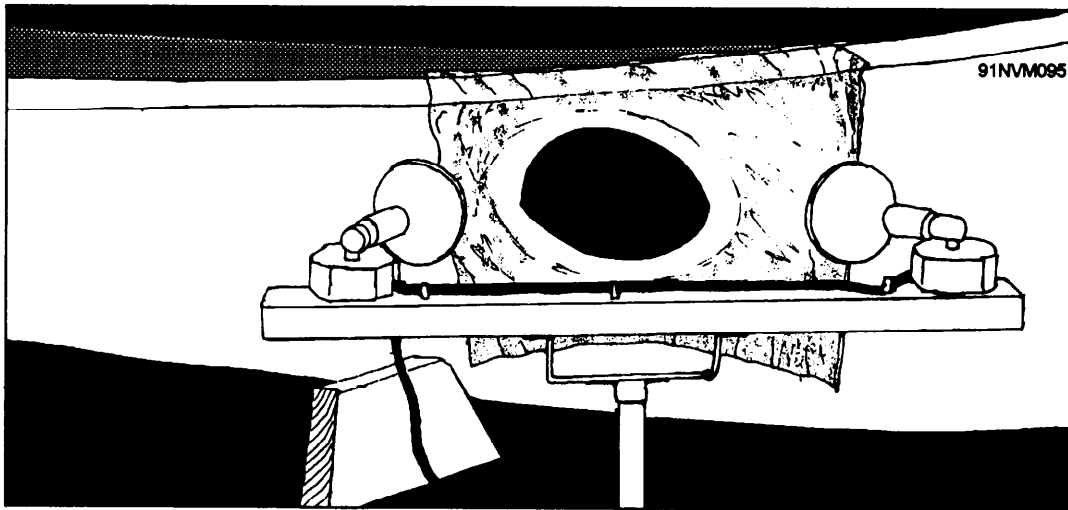
Figure 4-15.—Heat lamps in position to speed the cure.

this if heat is applied; but, in either case, the patch should be hard and cool to the touch before proceeding. Remove the cover plate and the separating film. If it is necessary to do so, fill in surface pits with the paste resin mix provided in the kit. Inspect the repair for soundness by tapping it with a coin or a metal object. A dull thud will indicate softness, poor bond (delamination) between plies, or poor bond to the original material. In the event that the patch is of poor quality, and the effectiveness of the

patch is in doubt, cut out the section slightly larger than the original patch and redo the repair. Assuming the job has been done properly, lightly sand the surface (fig. 4-16). The finish may be a coat of resin or paint.

REPAIRING SURFACE DEFECTS.—The repair kit contains an epoxy-type paste resin system for making minor repairs to damaged plastic surfaces such as seams, gouges, pits, or small holes. It can also be used for filling and smoothing patches made with

Figure 4-16.—Sanding a completed patch.

4-15

liquid resin systems and glass reinforcements, and for repairing minor damage to other materials such as wood and metals. Clean and abrade around the damaged area. Then, squeeze out the required length of paste resin from the tube. Parallel to the resin, squeeze out an equal length of hardener. This may be done on a flat surface that is covered with a piece of separating film. Mix the two materials with the small mixing stick. The resin is white and the hardener is black; when properly mixed the blend will have a uniform gray color. Spread the mixture over the damaged area with the mixing stick or a putty knife. Cover the repair with a piece of separating film and, with a clean mixing stick or spreading tool, smooth the resin from the center outward to obtain the desired contour. Finish the patch as previously described.

Bolthole Repair

To repair a slightly elongated or oval bolthole where the washer or bolthole still bears on the laminate, slightly abrade the enlarged portion of the hole with a file or sandpaper. Then fill the area of clearance around the fastener with the paste resin mix.

To repair a badly damaged bolthole, perhaps caused by a bolt pulling through the laminate, remove the bolts and separate the primary structure from any secondary member where necessary. Cut away the damaged surrounding area with a metal-cutting saw as before. From this point, follow the same plastic boat repair procedures described earlier in this chapter. Put extra plies of reinforcement in this area to provide additional strength. After the repair is completed, drill new boltholes-this time with proper clearance and bearing area. To prevent recurrence of such a failure, replace the bolts and washers with a larger size or a reinforcing plate.

Repairing a Damaged Reinforcing Member or Stiffener

The stiffeners used in reinforced plastic structures may be of various shapes that are either integrally molded with the plating or secondarily bonded to the plating. Figure 4-17 shows some typical stiffened panel constructions. Failure may be the result of poor bonding (in the case of secondarily bonded stiffeners), inadequate design, or unusual service loads. It is necessary that such failures be repaired as soon as possible to avoid further damage to the structure.

When you begin the repair, keep in mind the cause of the failure and correct any defects to prevent similar failure later on. For example, if failure is in the bond, is it the result of insufficient bond area, peeling action, or poor bonding technique? Examine the bonded area to ascertain if a uniform and sufficient amount of adhesive was applied. Compare the amount of the area that failed within the laminated part with the area that failed in adhesion at the laminate surface to see if the surfaces were improperly prepared. Surfaces should be carefully sanded and cleaned before bonding. Any repair should be aimed at preventing future failures.

If a stiffener has broken and must be replaced, the method of repair will depend on whether it has been integrally molded as shown in view A of figure 4-17 or bonded in place as shown in views B and C. In the latter cases, the entire stiffener may be completely removed by delaminating the bond, and a new stiffener fabricated by the WET LAYUP technique shown in view B of figure 4-17, or molded separately and bonded to the plating. The use of positive fasteners, at least at the ends and center of the stiffener, is often desirable where service loads are such that a possibility of peeling exists.

In the case of integral stiffeners, the damaged portion should be cut away to the extent necessary to assure stiffeners a satisfactory repair, and this area replaced, taking care that a good bond to the plating and adjacent members is obtained.

Repairs to stiffeners may be accomplished with the materials provided in the repair kit and simple wooden forms, using the repair techniques previously described. All surfaces to be bonded must be sanded and cleaned to assure good adhesion. The cross section and size of the replacement stiffener should be increased where necessary to provide additional bonding area or strength.

Repairing Glass-Reinforced Plastic Coatings

Damaged portions of glass fiber-reinforced resin coatings on wooden boats and other structures can be repaired with the resin and glass reinforcement supplied in the repair kit. The steps for this repair procedure are outlined as follows:

1. Cut away any loose or damaged sections of the glass-resin coating.

2. Repair or replace any of the wood that has been damaged. Fill seams and cracks with water-mixed wood putty or plastic wood. The resin and hardener or epoxy paste supplied in the kit may be used for filling. DO NOT use oil-base putty.

A. INTEGRALLY MOLDED

FAIR IN TO SKIN — PARTING FILM — REMOVABLE FORM

B. WET LAY-UP BOND

ADHESIVE BOND

C. SECONDARILY BONDED

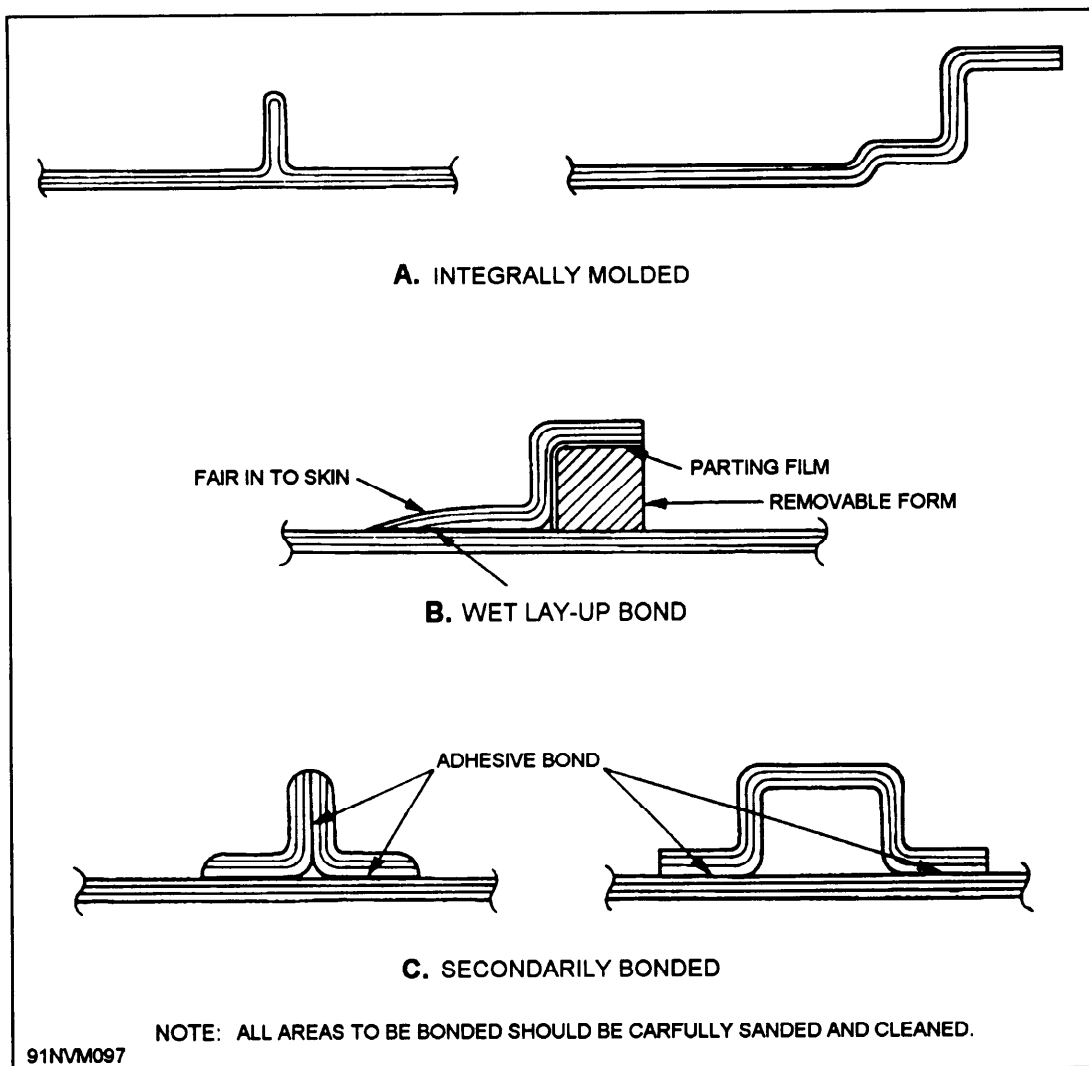NOTE: ALL AREAS TO BE BONDED SHOULD BE CARFULLY SANDED AND CLEANED.

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Figure 4-17.—Typical stiffeners.

3. After the putty has hardened, sand the area to be repaired down to the wood and sand the surface of the resin-coated glass to produce a 6-inch wide abraded surface around the void.

4. Cut the same number of plies used for the original coating and tailor these to fit the patch and the abraded area around it.

5. Based on the amount of cloth used for the patch, estimate the amount of resin needed. Mix the liquid resin and hardener.

6. Paint a liberal coat of the resin-hardener mixture over the abraded wood and over the abraded adjacent area.

7. Place one of the plies of cloth over the painted area and coat it with additional resin-hardener mixture. Lay up the remaining plies in the same manner. Place a

sheet of separating film over the glass-resin layup and work out the entrapped air and excess resin by stroking from the center outward with the spreading tool. Tape the film in place.

8. After the patch has set, remove the separating film. Sand off any excess resin or irregularities. If the patch is to be painted, sand the surface lightly before painting.

Large Hole Repairs

In repairing large holes that completely penetrate the laminate, mark the damaged area with chalk, as shown earlier in figure 4-8. Using a reciprocating sabre saw, cut away the damaged area enclosed by the chalk mark. (See fig. 4-11.)

4-17
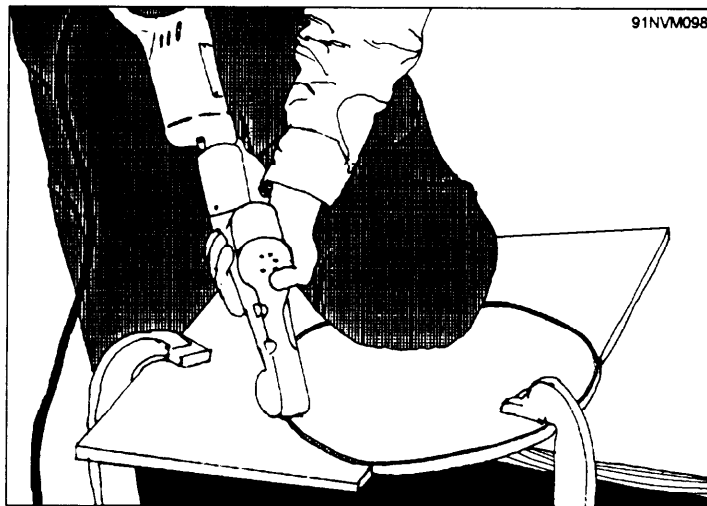
Figure 4-l8.—Cutting the patch from preformed laminate.
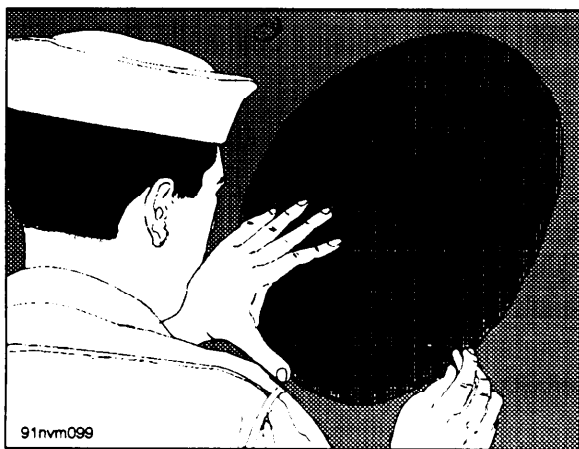
Figure 4-19.—Delineating the area where the scarf will extend on the area being repaired.

After the damaged area has been cut away, cut the patch from a section of preformed laminate of about the same thickness as the area being repaired. (See fig. 4-18.) Center the preformed laminate over the area being repaired and mark off the area to which the scarfing will extend, as shown in figure 4-19. If the opposite side of the area being repaired is accessible, make a second chalk mark conforming to the hole size on the preformed patch, as shown in figure 4-18. This delineates the extent of the scarfing to be done on the preformed patch. In case the opposite side is inaccessible, a template may be required to mark off this area to which the scarfing must extend on the patch in order for it to fit. Scarf the area around the hold so that a gradual taper extends back to the chalk mark, as shown in figure 4-12. Repeat this procedure
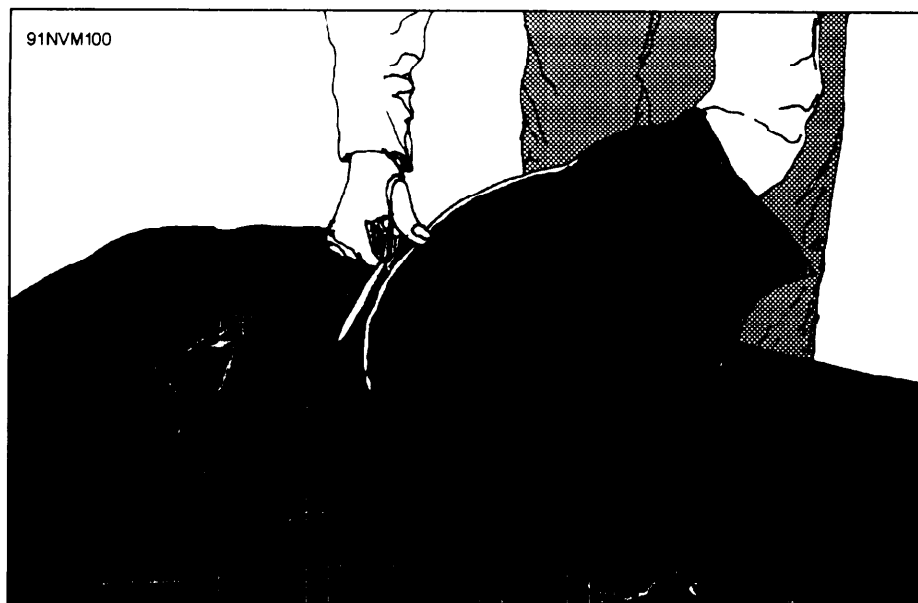
Figure 4-20.—Tailoring reinforcement. Laminate has been scarfed to fit level on the area to be repaired.

with the preformed patch. Check to be sure that the preformed laminate fits snugly over the hole. It should if the preformed patch and the damaged area have been properly scarfed. No backing plate is required when making this type of repair.

To make the reinforcement material, use the preformed patch as a pattern as shown in figure 4-20 and cut two or more bonding plies of glass cloth. The reinforcement material should be cut slightly larger than the preformed patch.

After the resin and hardener have been mixed, apply a coating to the scarfed section of the area to be repaired. (See fig. 4-21.) Then, coat the scarfed side of the patch piece with the resin mixture, as shown in figure 4-22.
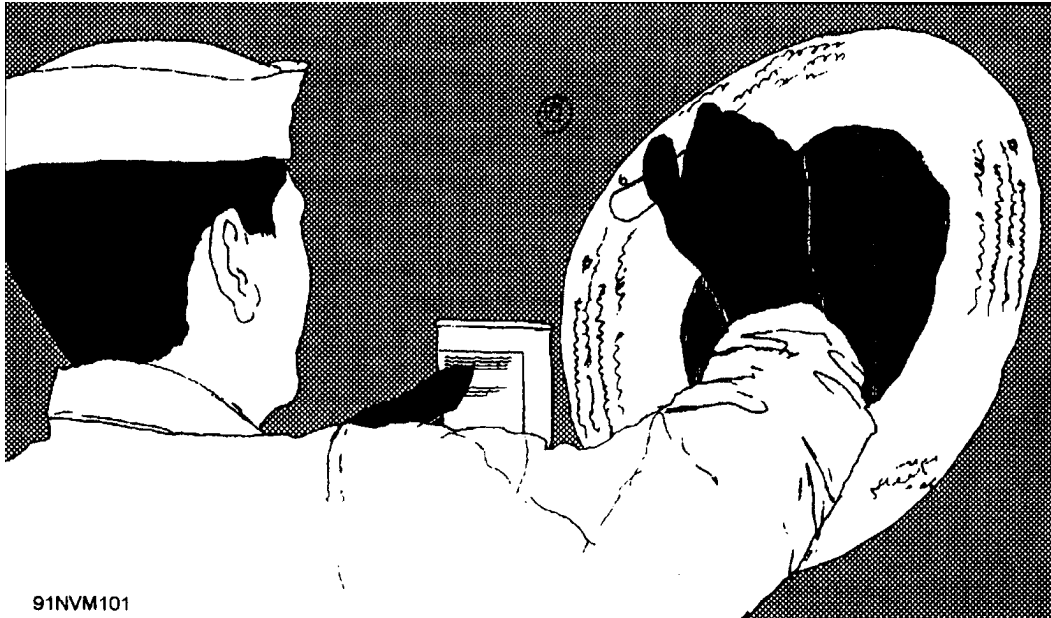
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Figure 4-21.—Coating the scarfed side of a damaged boat.
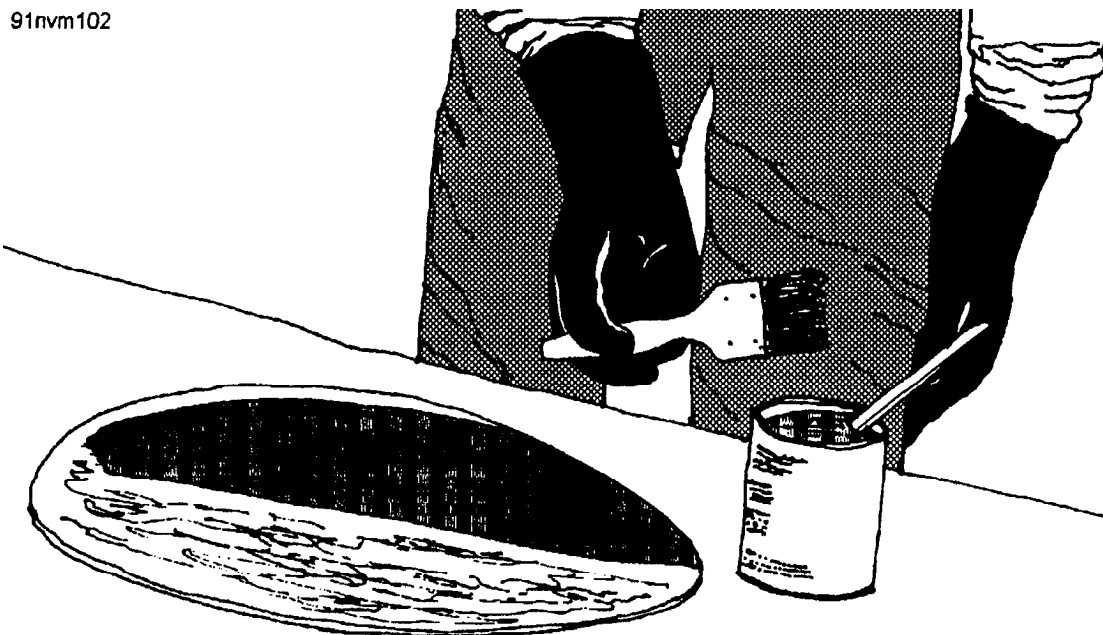
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Figure 4-22.—Costing the scarfed side of the laminate patch.

Center a bonding ply over the preformed patch as shown in figure 4-23, and saturate it with resin. (See fig. 4-24.) Repeat this procedure with the other bonding plies. Position this assembly over the hole as shown earlier in figure 4-14, and cover it with a sheet of separating film. The patch can be held in place by a cover plate, or by shoring as shown earlier in figure 4-13 until the patch hardens or cures. The patch is completed in the same manner as previously described.

Repairing Double-Skin Plastic Boats

To repair damage that extends through both skins and the core section of plastic boats, follow the procedures described earlier under repair procedures. Cut out the damaged areas and prepare the skins for

Figure 4-23.—Centering the first bonding ply.

patching by abrading the scarfs around the holes. Patch one skin and allow it to cure. After this patch has cured, cut and fit the core section. Secure the core section with repair resin. Then, repair the second skin.

Where damage is to only one skin and core, cut out a circle of skin with a sharp-cutting tool such as a hole saw. Cut the skin away from the core material with a knife. Damaged honeycomb core can be cut with sharp shears and pulled out with needle nose pliers. Other types of core material, such as plastic foam, can be cut out with a knife. Cut a piece of core material to fit the section that was cut out. Be careful to match the pattern, if necessary. Cement the material in place with repair resin and proceed to repair the outer skin as described previously.

Damage to the skin only can be repaired in the same way as a conventional repair to reinforced plastic.

METAL BOATS

From a wide range of aluminum alloys available for many purposes, the Navy selected those most suitable for salt water use for boat hulls. The hulls of Navy aluminum boats are usually constructed of either alloy 5086 or 5456. Both alloys contain magnesium as the primary alloying ingredient, but differ slightly in strength. In general, these two alloys are not used in combination except when emergency repairs are needed.

Figure 4-24.—Saturation of the bonding ply with resin.

Alloy 6061 is a general-purpose structure alloy using a combination of magnesium and silicon as the chief alloying ingredients. Its use in the Navy should be restricted to auxiliary systems, such as piping and railings, and to nonwelded structures.

Two other alloys that may be found in limited quantities are 5083 and 7039. These are used only for armor and are supplied especially for that purpose. As such, they should not be used for other structural areas of an aluminum boat.

Aluminum alloys are not identifiable by appearance and, therefore, are usually appropriately marked with alloy and temper designations. The temper designation follows the alloy number and indicates the degree of tempering. Tempering is done in two ways depending on the alloy: either by strain hardening or by the heat-treatment process. An alloy that has been strain hardened has a designator consisting of the letter *H* and a number, while an alloy that has been heat treated has a designator consisting of the letter *T* and a number. Thus, a plate labeled 5086-H116 has been strain hardened, while one marked 6061-T6 has been heat treated. Any alloy will be one or the other; for example, all tempers of 5086 begin with H. The exception is when aluminum is in the soft, or annealed, condition—indicated by the suffix 0. Thus, both 5086-9 and 6061-9 (and others) are available. The temper of material is of concern to the repairer, since it is desirable to make replacements of damaged areas with the same alloy and the proper temper.

Aluminum is a lightweight material, and it is for this reason that it is used for boats and craft. It is strong, weldable, and has excellent general corrosion resistance when proper marine alloys are employed. In the past, most interior spaces of naval boats were left unpainted in aluminum construction. There are, however, some precautions in the handling of aluminum that must be observed if the full corrosion resistance capability of aluminum is to be achieved.

As with many materials, although mild acidic solutions cause slight damage, caustic solutions of any sort such as sodium hydroxide, sodium carbonate, or sodium phosphate are particularly to be avoided; they cause severe etching of the aluminum even to the extent of resulting in perforation.

The most stringent precautions must be taken in the case of mercury. The presence of mercury even in small amounts on aluminum causes severe corrosive attack, and under no circumstances are the two metals to be permitted to come in contact with each other. Observing these precautions enables routine maintenance to be kept to a minimum.

Galvanic corrosion caused by a dissimilar metal contacting aluminum can occur. In marine applications, aluminum and its alloys are frequently the anodic metal and could corrode in preference to most other common contacting metals except zinc and magnesium. However, for galvanic corrosion to occur, the following conditions must be satisfied: a cell must be present consisting of at least two metals having different solution potentials and in electrical contact with each other (no matter how indirect), and a conductive medium (electrolyte) must be present between the metals.

Three applications account for most galvanic corrosion situations: (1) connections of aluminum deckhouse bulkheads to a steel boundary bar; (2) the attachment of steel or brass fittings to an aluminum structure; or (3) dissimilar metal appendages, such as rudders and propellers, on an aluminum hull.

Cleanliness is always important—dirty, wet bilges or accumulations of dirt and water anywhere are to be avoided. A freshwater rinse on a regular basis is generally sufficient.

ALUMINUM BOAT REPAIR

Cutting aluminum is more like cutting wood than steel. An oxyacetylene flame is not used because the excellent thermal conductivity of aluminum carries heat away too fast to get a good cut. In repair work, all cutting should be done mechanically using a circular saw, saber saw, or (in the shop) bandsaw equipment with metal-cutting blades. Use of a grease stick or lard oil will prolong blade life. Plasma arc cutting equipment is available for high-speed production work but is not needed for repair work. Shearing or punching of strained hardened alloys should be avoided.

Forming is done cold or hot. Aluminum does not change color with heat and does not glow red as does steel. Excessive heating can cause the metal to anneal to the soft condition or even melt or oxidize without any warning. Hot forming is done by carefully heating the metal to no more than 450°F. The temperature can be estimated by the use of temperature-sensitive crayons. Each crayon is formulated to melt at a different temperature; and by observing when the crayon markings on the metal melt, you can remove the heat source at the proper time.

Formed parts of a boat that have been damaged must not be re-formed using heat. When possible, it is suggested that the damaged part be replaced by new material formed for the job.

Distorted plates, whether caused by damage or the heat of welding, must not be straightened by flame-quenching (torch heating followed by spray cooling). The method does not work well and can result in over-heating or melting as previously described. If the distortion does nothing more harmful than detract from appearance, it should be left alone. Otherwise, distorted shapes should be straightened cold, using jacks as necessary, while distortion in plate panels may be relieved either cold or by making a saw cut in the center of the panel and rewelding it. When you weld a saw cut, ensure that the correct alloy is used. Cracking of the weld will result if the alloy of the filler metal or authorized alternate is not used. The normal shrinkage associated with aluminum welding will tend to remove the distortion.

The light weight of aluminum will facilitate repair by making handling easier. In addition, the preparation of subassemblies or repair sections in the shop is greatly facilitated.

If welding is impractical or impossible, use bolted aluminum alloy patches. For this type of repair, the following is needed: an electric circular saw for cutting plate to size and for fairing out any jagged edges in the hull penetration, and a good metal-cutting saw blade. After the patch plate is cut to size, connect it to the hull with aluminum or stainless steel bolts or other fasteners. In an emergency, any type of bolt will do. However, this must be considered a temporary repair since dissimilar metals cause galvanic corrosion. For bolting the patch to the hull, insert a sealing material around the perimeter. If a number of repairs of this type are anticipated, then it might be wise to provide several rolls of the sealing tapes used by aluminum small boat manufacturers. Most major tape manufacturers supply these tapes in various thicknesses and widths. These are the tapes used on modem day aluminum small boats and they do a good job, not only in sealing the seam, but also in keeping the rivets and bolts from leaking. The holes for the rivets or bolts will, of course, be made by a rotary drill.

If the boat incurs damage in a remote area where there are no facilities for welding, and aluminum is not available, temporary repairs can be made with steel patches. Some type of insulation, such as neoprene, should be used between the aluminum and steel, if possible. Large, temporary hull repairs can be made in this manner. The damaged area can be cropped out. The steel repair plate, including structural framing members, can be prefabricated by welding, leaving sufficient lap for mechanical fastenings. The unit can then be bolted to the aluminum hull with insulation between them. Splices can be made across the structural members. If tapes or neoprene are not available for insulating the steel and the aluminum, material such as Butyl rubber, polysulfide, or any heavy-bodied flexible coating will do. Avoid wicking materials, such as flax or canvas, and the use of lead-pigmented compounds, such as red lead. The steel temporary repair should be replaced with the proper aluminum repair as soon as possible.

STEEL BOAT REPAIR

Permanent repairs of steel boats must be accomplished by qualified welders and nondestructive test personnel. Fabrication, welding, and inspections must be accomplished as required by the BoatAlt or applicable alteration or repair drawing. NAVSEA 0900-060-4010 and *NSTM,* chapter 074 (9920), should be used as guides.

UTILITY BOATS

In the following sections, the discussion will deal primarily with typical repairs made to utility boats.

When a boat is damaged, the HT is responsible for making the required repairs. As an HT, you must know the procedures for renewing a stem, stem frame, and engine foundation in a small boat.

In general, the procedures described for repairing utility boats are similar to those required for repairing motor boats, motor whale boats, and ships' boats for other types.

CHOCKING THE BOAT

Before beginning to work on a boat, you must get it into a safe position, retain its true form, and prevent further damage, Figure 4-25 shows a type of boat chock that you can construct aboard ship. It is simply a framework made from 4 by 4's and braced with 2 by 6 lumber. The number of chocks and other bracing should be determined so that the craft can be held reasonably rigid to a fixed position.

NOTE: When positioning chocks, ensure that they bear on the hull at structurally reinforced areas.

REMOVING DAMAGED PARTS

Remove damaged parts carefully since you will probably have to use them as patterns in making the new
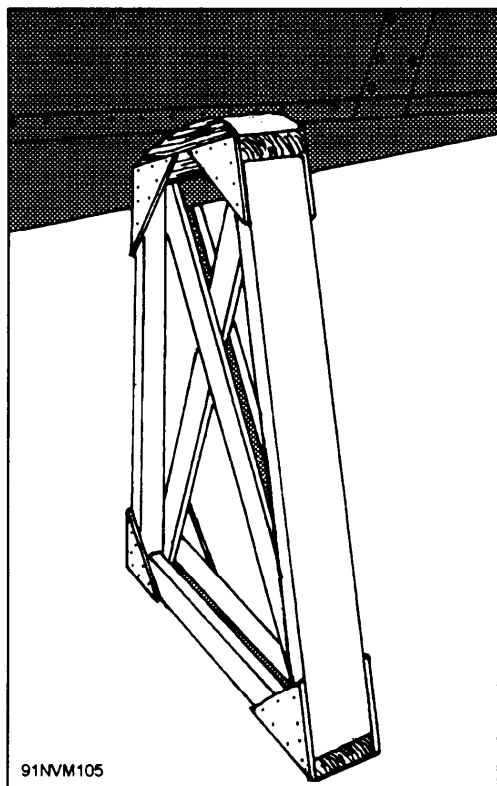
Figure 4-25.—Boat chock for shipboard use.

1. Stem Apron
2. Main Stem Piece
3. Stem Knee
4. Fore Foot
5. Keel
6. Stopwater
7. Bolts
8. Rabbet Line
9. Beading Line
10. Keelson
11. Filling Block
12. Floor Frame
13. Frame
14. False Keel
15. Stem Band

Figure 4-26.—Nomenclature of the bow structure.

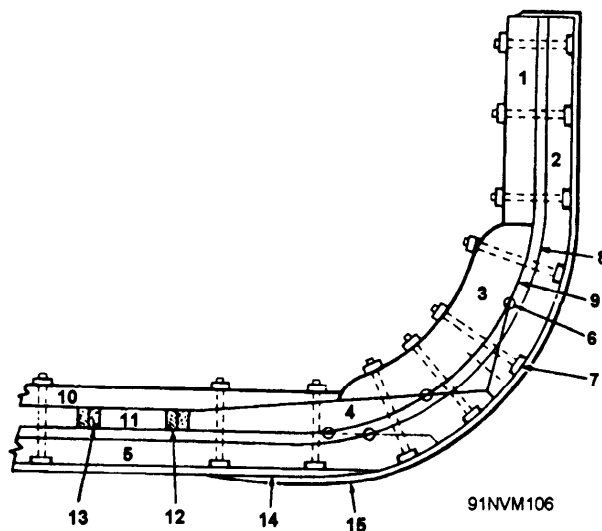parts. As an example of the procedure for removing damaged parts, a damaged stem can be removed as follows:

1. Carefully scrape the paint from the stem and from the planking as far aft as necessary, exposing the countersunk screw holes or the wood plugs over the fastenings.

2. Remove the metal stem band, chafing plate, and bow chocks. Also, remove the platform decking to clear way for work.

3. Remove the brass bolts that secure the stem to the stem apron and knee. Work from the stem apron side, and use a drift pin to drive the bolts out. When the bolts are out, check them for defects; they may require rethreading or replacing.

4. Remove the brass screw from the stem where it joins the knee. Figure 4-26 shows the stem and stem apron assembly in relation to the keel, keelson, and knee.

5. Remove plugs or putty from the screw holes, in the hull planking, and back out the screws to about one-half their length. In backing out the screws, start aft and work forward; except where hull planking is damaged, all of the damaged material should be removed. Do not remove any of the screws completely until all of them have been partially backed out and the planks have become loosened from the frames and rabbet. If the planks do not come loose immediately, remove putty and caulking cotton from the seams and tap the planking gently with a rawhide mallet, on the frame side, to help break the seal.

6. When the seal is broken and the planking comes free from the frames, run a line around each plank and fasten it to frame 2. This prevents the planking from springing out and breaking loose farther aft if it becomes necessary to remove the screws completely to pull the stem apron.

7. Pass a line through the uppermost bolthole in the stem and apron, and secure the line to a thwart. This precaution is necessary to keep the stem and apron from falling to the deck when the assembly is freed.

8. Remove the breasthook. Then, the stem assembly will be completely freed.

9. Clean the stem and remove all putty, white lead, and any foreign matter from the rabbet so that the stem will form an accurate pattern piece.

REPAIRING THE STEM

After the damaged stem has been removed and cleaned, use it as a pattern in making the template. Lay the damaged stem on a piece of 1/4-inch plywood and block it in a near-level position. Then, trace the outline

with a pencil. Be sure to keep the pencil vertical so that the boundaries of the template will be the same as the boundaries of the stem. Check the boundaries by using dividers as a test gauge. Then cut the plywood on the penciled lines, and smooth the template with a plane.

To lay out the rabbet, set the dividers at the distance from the back of the damaged stem to the outside of the rabbet; then put the dividers on the template in the same relative location, and mark the template. Repeat this procedure along the entire length of the stem, at approximately 1-inch intervals, so that the rabbet line will be marked all the way along the template.

Next, place the template on the lumber, as shown in figure 4-27, making sure that the maximum strength is obtained by avoiding as much cross grain as possible. Mark off the stem on both sides of the lumber, according to the template; allow 6 to 8 inches excess length above the capping.

Remove the template, and cut the new stem. Use a bandsaw to cut within 1/32 inch of the lines; then finish by planing to the lines. Lay the template on the piece again, and drive small nails through the template along the rabbet lines. Drive the nails entirely through the template and into the piece so that the rabbet lines will be marked on the piece by the small nail holes. Then, remove the template and drive small nails into the holes in the new piece. Draw pencil lines from nail to nail, and you will have the rabbet lines marked on the new stem. Figure 4-28 shows the procedure for transferring rabbet lines.

Chisel a series of notches on the rabbet lines. Be careful that you do not remove too much wood; additional paring may be done when the planks are being fitted to the stem. In cutting the rabbet, use a piece of planking as a template. Make the steam apron by copying the damaged piece. You do not have to make a template, since you can use a bevel square to get the bending lines and a rule and compass to determine the overall size. The bevels are set on the bandsaw; the cuts are then made; the piece is then trimmed to the lines on the jointer.

The new stem and the new stem apron must be very accurately fitted. It is essential to drill the lowest bolthole on the stem so that it will match up EXACTLY with the bolthole in the knee. The best way to make certain that the lowest bolthole on the stem is aligned with the bolthole in the knee is to clamp the stem to the knee (using C-clamps and blocks), and then drill through the bolthole in the knee. Be careful that you do not enlarge the bolthole in the knee while you are drilling through the stem.

After this first bolthole has been drilled in the stem, insert a bolt of the proper size and type and draw it taut. Then remove the C-clamps and the blocking. Place cabinetmakers' clamps over the stem and the knee, at each end. Then drill the second bolthole, insert the bolt, and draw it taut. The completion of the job from this point is just a matter of fairing in, fitting, white leading, shaping the stem to correspond to the width of the forefoot, tapering off to the full width at the top, and drilling holes for stopwater. Do not try to drill the holes for stopwaters until after the stem has been set in place.

Any damaged planking should be replaced at least six frames aft of the stem to ensure a substantial planking jott. If more than one plank must be replaced, be sure to stagger the after end joints of adjacent planks so that they are at least two frames apart. Figure 4-29 illustrates a completed stem repair job. Notice that the boltholes are ready for plugging, and the two new planks are ready for caulking.
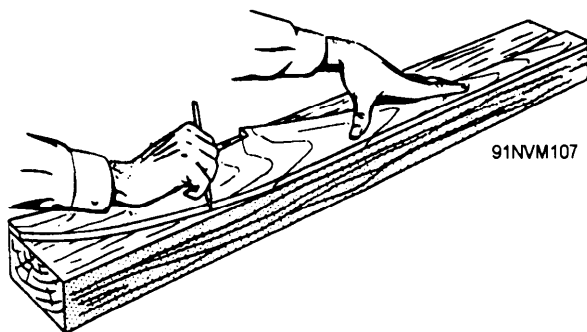

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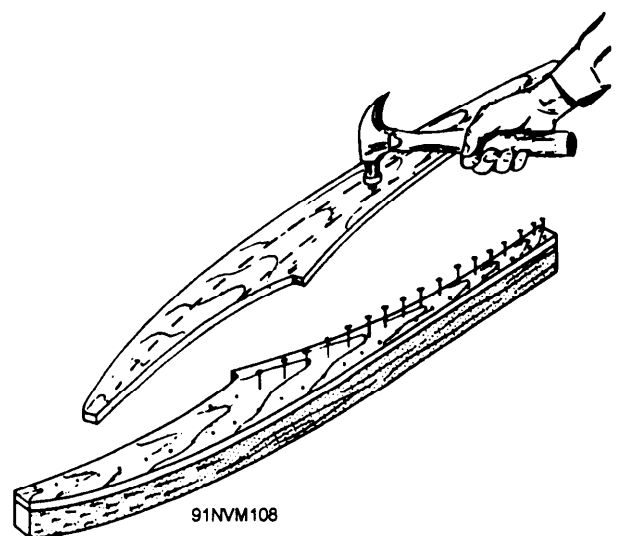**Figure 4-27.—Using the template.**

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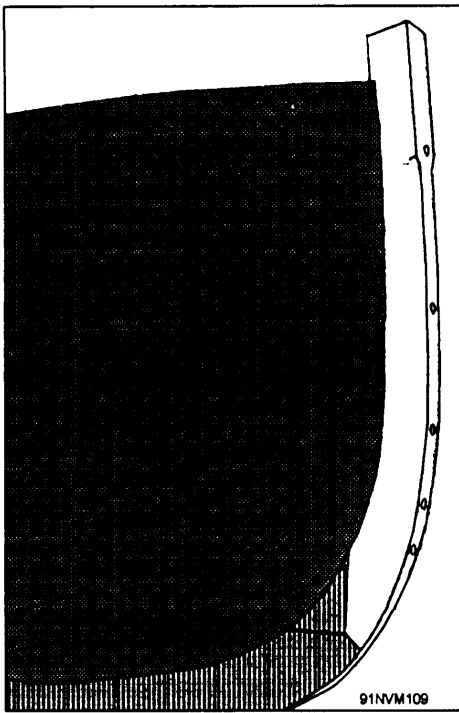
Figure 4-28.—Transfer of rabbet lines.

Figure 4-29.—Completed repair to a stem.

REPAIRING THE SHEER CLAMP

Suppose the sheer clamp is split from the apron to as far aft as the sixth or seventh frame. How would you proceed to repair the damage? First, remove the sheer cap as far aft as necessary to enable you to work on the sheer clamp and the sheer strake. Then remove the sheer strake by cutting the proper rivets and driving them from the frames and the clamp. Because of the twist and curvature of the damaged piece, you will have to remove the sheer clamp much farther aft than the end of the split. When you have decided where to cut the clamp, remove the clamp filling blocks for as many frames forward and aft as necessary to allow you to cut the clamp. Then saw through the clamp, and remove the damaged piece.

Select a new piece of timber for the replacement piece. Surface the piece to the correct thickness, length, and width, and lay out the scarf joint. Be sure to make the scarf joint of the proper proportions; the length should be at least six times the depth. Cut to the lines, and smooth the wood with a sharp chisel and a plane.

Make a pattern of the finished scarf, and transfer the lines to the undamaged section of the clamp. Cut and smooth the scarf on the undamaged section, as you did on the new piece.

Steam the new piece and bend it to the proper shape. Using C-clamps or cabinetmakers' draw clamps, clamp the new piece in place from the scarf end forward, and reinstall the filling blocks. Drill the scarf joint for carriage bolts, insert the bolts, and tighten the nuts over washers. Figure 4-30 shows the completed scarf on the sheer clamp.
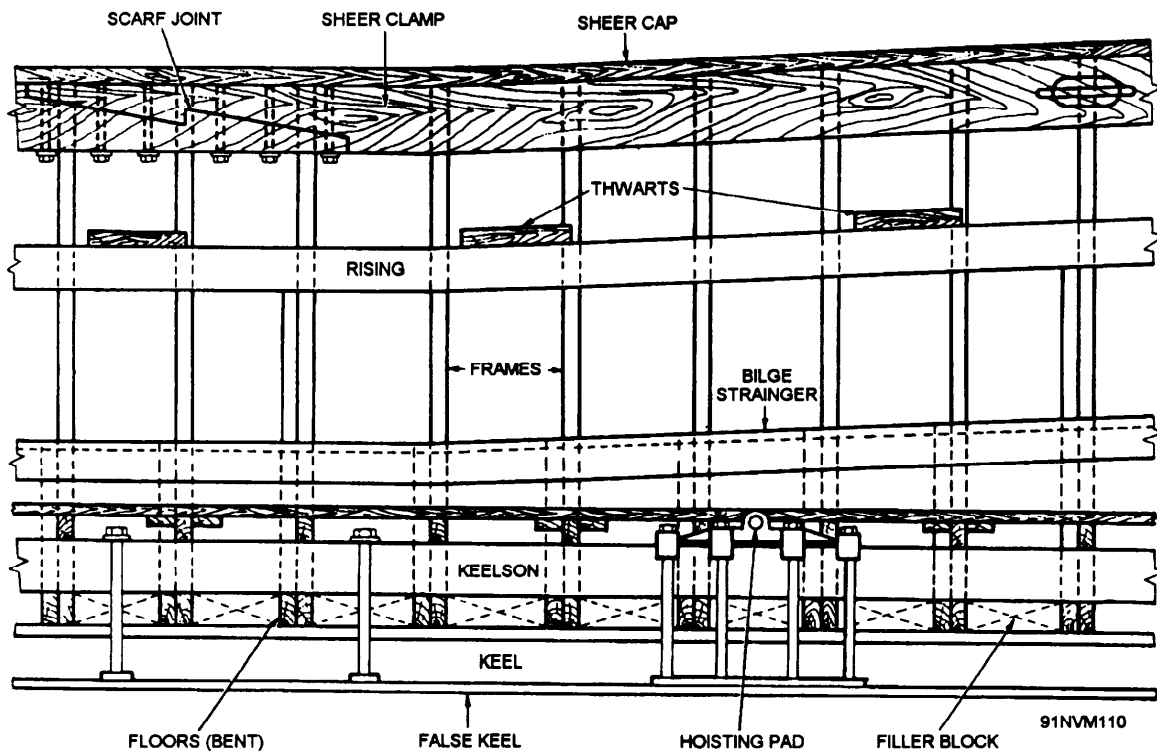
Figure 4-30.—Completed scarf joint on the shear clams.

Loosen the draw clamps and replace the sheer strake. Then put the clamps on again and draw them taut. Using the existing rivet holes in the sheer strake as a guide, drill holes for 1/4-inch copper rivets. Then rivet the clamp to the breast hook. Nail the sheer strake in place, using 4-inch copper nails, and trim the upper edges to conform with the camber. Then install the capping, and the repair job is finished except for caulking, sanding, puttying, and painting.

REPAIRING THE STERN

Let's assume that you have to renew a transom bounding frame, the stern-post knee, and deck supports on a wooden boat. Figure 4-31 shows details of transom construction. Figure 4-32 shows the outer bounding frame of the starboard transom, ready for repair. Note that the transom angles have been removed, and the paint has been scraped off.

To remove the outer bounding frame, you must also remove the inner frame. To do this, you must strip the after-deck area of the rudder assembly, taff railing, and all hardware; and then remove the decking. Figure 4-33 shows the stem with the hardware and the decking removed, but with deck supports still in place. Figure 4-34 shows the deck supports and the transom knee.

Remove all screws that join the transom planking to the inner frame, and remove the copper rivets that fasten the transom planking and the outer bounding frame to the inner bounding frame. The outer bounding frame is a filler piece, and will come free when the seal is broken. The inner frame, which is in four pieces, should be removed to the joint nearest the break. The procedure for laying out, cutting, smoothing, and fitting the replacement pieces is the same as that previously described for other members.

RENEWING ENGINE FOUNDATIONS

Procedures for renewing engine foundations vary considerably, depending upon the type of boat. In
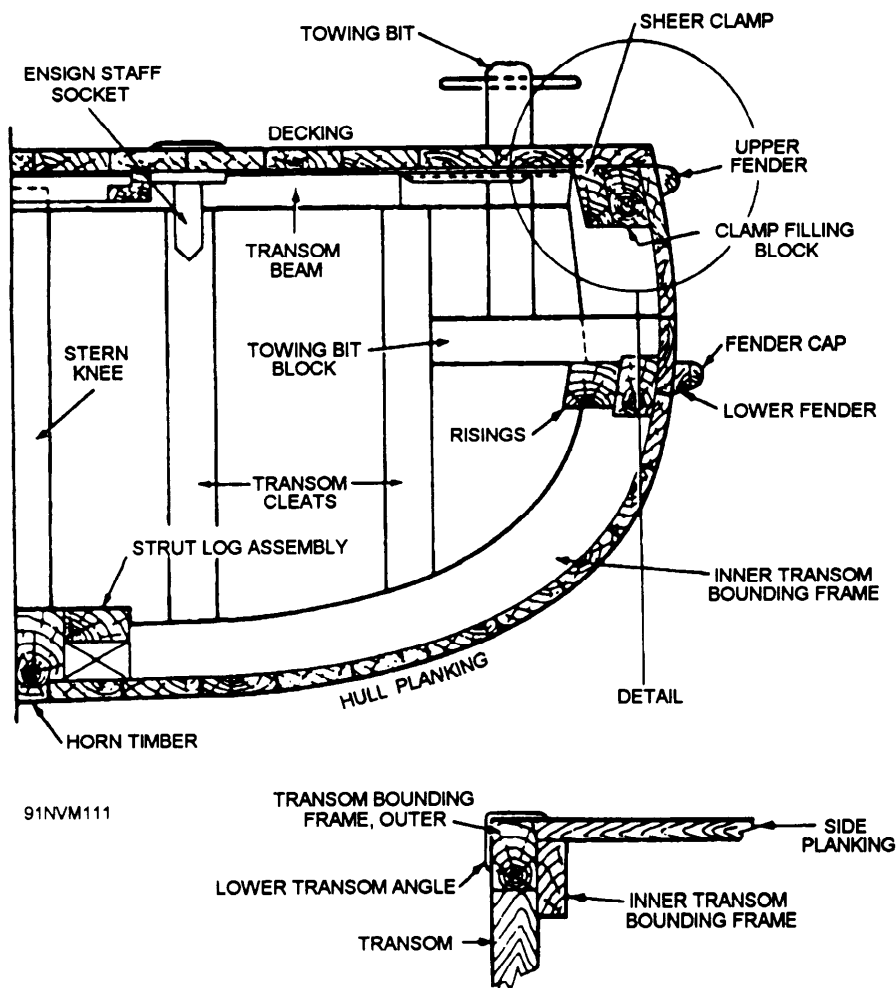
Figure 4-31.—Transom construction.
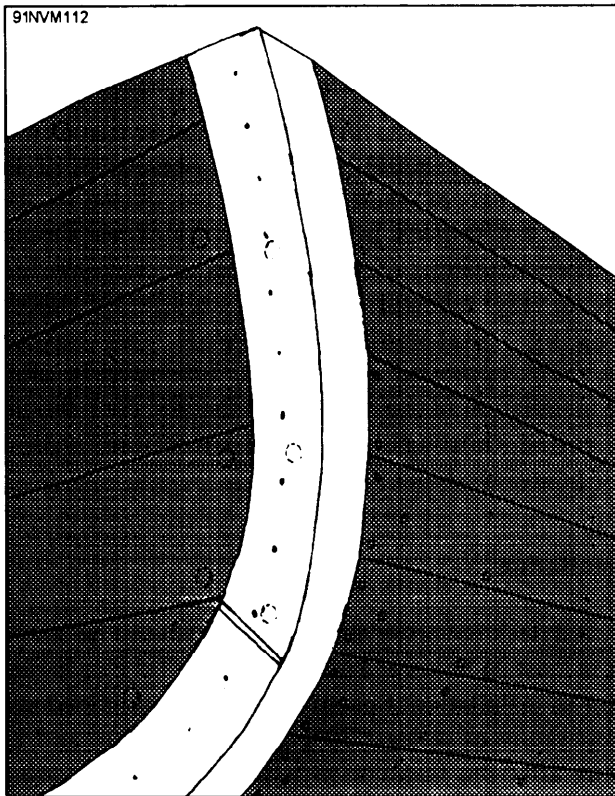
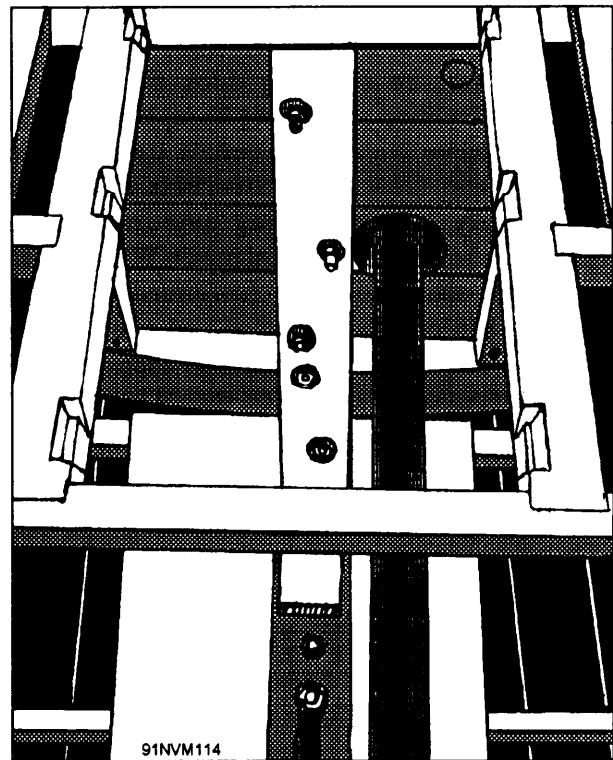Figure 4-32.—Outer bounding frame, starboard transom.
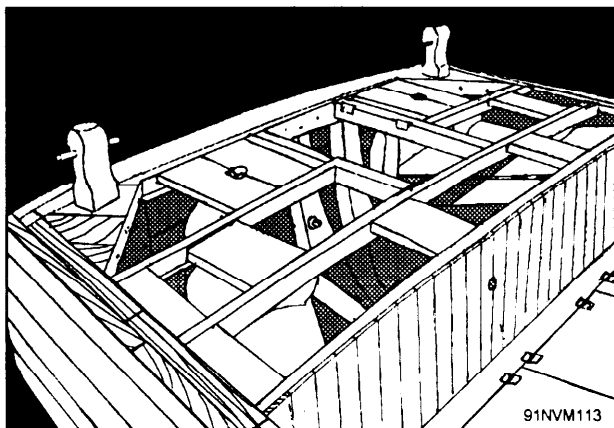

Figure 4-34.—Deck supports and transom knee.

Figure 4-33.—View of stern, with decking removed.

performing this job, remove the engine and the damaged pieces carefully so that you can use them to make templates.

As a rule, the engine stringer is secured to the floor timber with rods. Since the nuts are on the face of the stringer, you must back off the underneath planking so that the rods may be removed, when necessary, to replace the stringers or defective parts. The engine bed is usually secured to the engine stringer with bolts. Engine hold-down bolts are installed with the heads at the seam between the engine bed and engine stringer. These bolts protrude upward about 2 or 3 inches above the top of the engine bed, and the engine is fitted over the protruding end. A nut is used on each of these bolts to hold the engine in place. Gaps are cut at the seam between the engine bed and the engine stringer to allow access to the heads of the hold-down bolts.

DECK COVERINGS

The qualities required in deck coverings for naval ships include nonflammability, wear resistance, lightness of weight, slip resistance, ability to protect steel decks from corrosion, good appearance, and ease of maintenance. Simplicity of application and the initial cost of the material are also important considerations.

A number of different kinds of deck coverings are available. However, deck coverings used in any area aboard ship must be according to NAVSEA instructions and specifications. Information on deck

coverings that are not discussed in this chapter may be obtained from *NSTM,* chapter 634.

In general, an existing deck covering in satisfactory condition should not be replaced even if it does not agree with the materials listed for the specific space. New deck coverings should be installed only where existing authorized deck coverings are beyond economical repair. When repairs are required, they should be performed locally if possible. When complete removal and reinstallation of a new deck covering is required, an approved deck covering for the specific location should be installed.

A deck covering should cover the entire deck area of a compartment unless otherwise specified, except that it should not be installed under enclosed built-in furniture nor under equipment with enclosed foundations.

Before laying any type of deck covering, be sure that the deck is clean and free of rust, loose scale, and dirt; grease and oil should be removed with solvents and clean rags. Paint and primers that adhere strongly to the deck may be left intact unless otherwise specified.

Certain adhesives and compounds used in the application of deck coverings contain flammable solvents. Safety and health measures to be taken depend upon the flash points and toxicity of the solvents. Be sure to comply with all applicable safety precautions.

FIRE-RETARDANT DECK TILE

Marbleized fire-retardant vinyl tile, one-eighth of an inch thick, is the standard Navy deck tile approved for shipboard use. Vinyl tile is stocked in eight marbleized colors.

Deck tile should be laid over bare wood, plastic, or cleaned base metal that has been primed with formula 150 MIL-P-24441. Tile must not be installed more than two layers thick because the additional layers increase the fire hazard. In general, when laying new tile, remove tile down to base metal or wood if two layers have previously been installed. Prime the deck to prevent corrosion if it is made of metal.

Fire-retardant deck tile should conform to MIL-T-18830 or other NAVSEA-approved equivalent, and they should be installed with a latex cement, except in damp or wet areas where it is advisable to use an epoxy adhesive.

RUBBER TILE OR ROLL DECKING MATERIALS

The tile and the roll decking must meet the fire requirements of MIL-STD-1623. Rubber tile or roll deck coverings should be installed one-eighth of an inch thick, except where durability is required for the heaviest traffic areas. In this case, the thickness should be three-sixteenths of an inch. The adhesive used to cement vinyl asbestos tile may be used for the rubber decking materials, as well as other NAVSEA-approved equivalents. Immediately after the installation of the rubber decking, the deck should be rolled thoroughly in both directions with a 150-pound sectional roller.

Installation

All deck covering and adhesives should be stored for at least 24 hours at a temperature of 70°F or higher prior to installation. Spaces should be maintained at a temperature of at least 70°F prior to, during, and 24 hours after the installation is completed. A beading sealer should be used to waterproof all seams against bulkheads, stationary furniture, pipes, and other deck fittings. Where weld lines (beads) prevent the deck covering from butting tightly against the ship's structure, caulking compound should be used to fill the gap, and painted to blend with the deck tile or bulkhead after the caulking compound skins over. Alternatively, weld lines against bulkheads may be made even by filling underlay material and the tile butted against the bulkhead. This latter method produces a better appearance. If desired, the tile may be squared off where it is in the way of vertical stiffeners and stanchions.

Preparation of Steel Decks

Steel decks must be clean, free from oil, grease, rust, and loose scale. It is not necessary to remove red lead or zinc-chromate priming paint, or deck paint if they are well bonded to the deck; otherwise, loose paint, rust, and scale should be removed by blasting, wire brushing, or any other effective method. The deck should then be washed with approved solvents to remove grease and contaminants and the steel primed with formula 150, 2- to 4-mils dry-film thickness. If possible, weld seams should be ground flush with the deck, and all low spots should be filled with underlay, MIL-D-3135, type II. All high spots should be ground down, if possible, or faired with underlay before

applying the primer. The deck must be dry at the time the deck covering is installed.

Application of Deck Tile

Installation pointers for laying rubber and vinyl tile are as follows:

1. Store the tiles for 24 hours at a minimum temperature of 70°F. (At temperatures below 70°F, the material is not sufficiently flexible for satisfactory installation.) To ensure straight seams, square off the areas to be covered and, if practicable, start the installation of tile at the center of the space and work to the edges to achieve an even balance of tile around the edges of the space.

2. If a pattern of two or more colors is desired, plan this on graph paper in advance (each square of the paper can be considered one tile). For spaces with nonparallel opposite bulkheads, use a large square and chalk line at corners to square off the compartment into a rectangular or square layout. To locate the center of the space, strike a chalk line from the midpoints of opposite bulkheads after squaring off.

3. It is important that installation start at sections of the space where work can proceed to completion without kneeling on freshly laid tile. Cement should be spread with a fine-toothed trowel (approximately 1 square yard at a time) at a coverage of 100 square feet per gallon (excess cement will reduce adhesion). While the cement is tacky, force the tiles into tight contact with each other. Half tiles can be cut by scoring and cutting through with a sharp knife. Vinyl asbestos tile should be made flexible by heating before cutting. A dull or unpointed linoleum knife should not be used for cutting the tiles because uneven edges will result.

Care also should be taken that the cement does not get on the surface of the tiles. Excess cement may be cleaned off, while wet, with a damp rag. If cement is dry, a rag that has been wet with paint thinner will remove the cement. Pressure should be applied to ensure complete contact of each tile with the deck. Any high joints remaining after this operation should be rubbed even and smooth with a hand roller.

4. Travel over the newly cemented areas should be restricted until the installation is completed; then the deck can be opened to foot traffic immediately since no indentations will occur from this type of traffic However, it is recommended that heavy concentrated loads, such as legs of heavy furniture, be kept off the deck until the cement has set (approximately 18 hours).

Water can affect adhesive and loosen tiles; therefore, swabbing the deck should not be done for 1 week after installation; for general cleaning, use water sparingly to prevent corrosion under tiles.

Installation of Rubber Roll, Vinyl Sheet, or Mat

When installing these materials in front of equipment only, cut the sheet to the desired length and, with a straightedge, cut off the selvedge (if applicable) before cementing the sheet. When installing sheeting material over an entire deck area, lay out the space, cutting all sheets to the desired length; then overlap edges of the sheet so all seams can be double cut, using a straightedge, to assure tight fit. After the material has been cut and fitted, roll the sheets back and cement half the space. Lay sheets down into position. Then repeat the process for the other half.

1. When cementing, use a latex-type adhesive conforming to MIL-A-21016. If a sheet has a tendency to bubble or lift after installation, it may be necessary to substitute a stronger adhesive such as an epoxy adhesive. The adhesive should be spread with a notched trowel, making certain that the entire surface is covered. When the adhesive is tacky, install the sheet. Immediately after installation thoroughly roll the deck in both directions with a 150-pound sectional roller.

2. For additional information concerning materials used to prevent electric shock, see *NSTM,* chapter 634.

Repair or Replacement of Deck Tiles

If a tile requires replacement, remove it by forcing a wide-blade paint scraper under it. Inspect for corrosion. Chip out the dried cement and corrosion products to bare steel, clean the spot with paint thinner, coat it with primer, and apply tile as previously described.

LATEX UNDERLAY

Latex underlay should conform to MIL-D-3135, type I, for use under latex terrazzo, latex, mastic, and ceramic tile.

Surface Preparation

Remove rust and paint. Clean the deck free of oil, grease, and dirt with an approved degreasing solvent. Apply one coat of epoxy primer, formula 150,

MIL-P-24441, 2- to 4-mils dry-film thickness, according to *NSTM,* chapter 631.

Surface Wetting Coat

One part rubber latex mixed thoroughly with 2 parts underlay powder by weight should be brushed on in a thin coat, assuring that all of the deck is wetted thoroughly. The purpose of the wetting coat is to assure that the underlay bonds securely to the surface.

Underlay Body Coat

Mix thoroughly 1 part rubber latex, 1 1/2 parts of underlay powder, and 1 1/2 parts aggregate (all by weight). Mix only in such quantity that the material will not set up before application. Make certain there are no dry particles left. The following approximate quantities of materials are required to cover 100 square feet (one-fourth of an inch thick):

49 lb rubber latex

73 lb underlay powder

73 lb underlay aggregate

While the surface wetting coat is still wet, trowel on the underlay body coat and level off with battens. After leveling off, go over the surface with steel trowels, working down hard to flow the mix together and to blend it with the surface wetting coat. Allow the surface to dry hard (at least 2 days) before applying the deck covering. If the underlay is used in excess of one-half inch thick in one layer, it will tend to develop hairline cracks. Latex underlayment for use under deck tile and resilient sheeting should conform to MIL-D-3135, type II, and should be installed according to the manufacturer's directions. Type II can be featheredged and trowelled to a smooth finish without sanding.

INSULATION-TYPE UNDERLAY

Insulation underlay may be used to prevent condensation such as occurs on ballast tank tops and heat from the overheads of machinery spaces, especially where these surfaces form the decks of living spaces. The magnesia insulation that is used should conform to MIL-D-23134.

Surface Preparation

Remove and clean the deck free of rust, dirt, old paint, oil, and grease. Apply one coat of epoxy primer,

formula 150, MIL-P-24441, 2- to 4-mils dry-film thickness, or an equivalent coating.

Installation

The on-deck magnesia insulation should be trowelled smooth, a minimum of 1 inch thick over rough finish latex underlay MIL-D-3135, type I. Apply a one-eighth inch minimum thickness of underlay. Exposed aluminum fittings should be protected from corrosive attack from the magnesia by either a coating satisfactory for aluminum (see *NSTM,* chapter 631) or a suitable covering such as a wrapping of a vinyl tape.

RUBBER TERRAZZO

Rubber terrazzo, which is used in washrooms, showers, sculleries, and water closets, is a colored material that contains chips of white and colored marble. The material is mixed at the time of application and is applied with trowels; it requires machine grinding to provide a smooth surface. The usual thickness of application is one-fourth of an inch. The material may be applied to a maximum of one-half of an inch without causing the wet mix to sag. If greater thickness must be used, apply latex underlay first.

The materials required for mixing rubber terrazzo are as follows:

● Liquid latex

● Grout powder

● Terrazzo mix (including aggregate)

● Sealer

Before rubber terrazzo is applied, the deck surface and 4 inches of vertical bounding surfaces against which the covering will abut must be cleansed by wirebrushing or similar methods. If necessary, the deck should be faired with underlay in low spots and around rivets and welds.

After the deck has been cleaned, give it a wetting coat of grout. Mix, apply, seal, and grind the terrazzo according to the manufacturer's instructions. Allow the terrazzo to dry for 72 hours before grinding it. After grinding, clean the deck with a broom or a vacuum cleaner. This should produce a smooth, durable, nonporous surface in which the marble chips are uniformly distributed and firmly embedded. Cover

the deck with sealer. Allow the sealer to dry, and then apply a second coat of sealer to complete the job.

NONSKID DECK TREADS

Nonskid deck treads are similar to a coarse emery cloth. The treads, which are approximately 6 inches wide and 24 inches long, are installed at the head and foot of ladders and at each side of doors with high coarnings that are used for continuous traffic. The treads are generally placed about 2 inches apart.

The treads, which have a pressure-sensitive adhesive backing, are cut from rolls or ordered in boxes of 50 each. The comers of the treads should be rounded before installation. Nonskid deck treads may be installed over finish paint or primers and over deck tile, provided the surface is free of grease, oil, floor wax, and dirt or dust. If nonskid deck treads are applied to unpainted steel decks, all dirt, rust, and foreign matter must be removed by wire brushing. The installation of these treads over a poorly prepared steel deck can result in severe deterioration of the deck.

After the nonskid deck treads are installed, they should be rolled with a weighted roller. The edges must then be sealed with an approved beading sealer.

MAINTENANCE OF DECK COVERINGS

Deck coverings should not be washed more often than necessary.

When necessary, they should be mopped with a damp mop, using a synthetic detergent solution. Two tablespoons of cleaner per gallon of warm potable water is recommended. Deck coverings should not be flooded with detergent solution; only a limited quantity of solution should be used. Using excessive quantities of water or detergent solution is damaging to the deck covering and may cause the covering to come loose from the deck.

Deck coverings should not be cleaned with strong alkaline soaps, abrasive cleaning powders, or salt water. All water, cleaning compounds, and dirt should be removed and the deck rinsed with clean, fresh water, using a damp, clean mop. Rubber heel marks, grease, and dirt may be removed with a rag moistened with paint thinner or by using fine steel wool and soap. After washing and after the deck is completely dry, the tile may be buffed with a buffing machine or it may be given a coat of wax and allowed to dry without polishing. A slip-resistant water emulsion type of floor wax is available and should be used when possible.

If a high gloss is desired, the dried wax may be buffed with a polishing machine. To conserve wax and reduce maintenance, a deck should be buffed several times before it is rewaxed. The deck may only require rewaxing in the traffic lanes once a week. If dirty spots are wiped up promptly with a damp rag and the areas are immediately repolished, a complete refinishing job may be deferred for a long time.

Do not apply lacquer, plastic, or other hard finishes to deck coverings. These finishes tend to become yellow and to wear off in traffic.

The most painstaking and careful maintenance of deck coverings may be wasted through careless treatment. The legs of furniture, especially chairs and other movable pieces, should be properly fitted with rubber tips to prevent scratching and denting of the deck covering. Nonslip rubber tips are available. Heavy objects should not be dragged across resilient deck coverings unless they are protected. Also, deck coverings should be protected with cover cloths and scrap materials during painting and during shipyard overhauls.

SUMMARY

With the knowledge gained on emergency repairs of small boats and the assistance of experienced personnel, you should be able to keep your craft operational until permanent repairs can be made. And if the need arises, the repair or replacement of the various types of deck coverings may be made, provided that the proper materials and equipment are available to complete the job.

CHAPTER 5

TOOLS AND EQUIPMENT

LEARNING OBJECTIVES

Upon completion of this chapter; you will be able to do the following:

● *Describe the characteristics and use of some special tools used by Hull Technicians in the performance of their duties.*

● *Point out the features, purpose, and techniques of using calipers, torque wrenches, gauges, and squares.*

● *Describe the setup, operation, and maintenance of various portable shop tools and machine power tools, and identify some of the safety precautions to observe when using them.*

● *Describe the construction and safety devices of compressed gas cylinders and the safety precautions to observe when handling them.*

● *Identify the color codes, test and repair procedures, and handling and stowage requirements of compressed gas cylinders.*

INTRODUCTION

Tools are designed to make a job easier and enable you to work more efficiently. Regardless of the type of work to be done, Hull Maintenance Technicians must have, choose, and use the correct tools to do their work quickly, accurately, and safely. Without the proper tools and the knowledge of how to use them, they waste time, reduce their efficiency, and may even injure themselves or cause others to be injured.

This chapter explains the specific purposes, correct use, and proper care of some of the specialty tools you may use, such as portable shop tools, machine tools, compressed gas cylinders pneumatic tools, portable power tools, and some installed shop equipment. The various tools discussed here are by no means all the tools that exist in this group. They are the specialty tools you will normally find in an HT shop. Equipment that is used only for one purpose, or in connection with one particular skill, is covered in the appropriate chapter or chapters of this training manual. It is not the intent of this chapter to introduce or instruct you on the use of every tool or piece of equipment you may encounter in the workshop. The material in this chapter is intended to supplement,

rather than repeat, the information in *Use and Care of Hand Tools and Measuring Tools,* NAVEDTRA 12085, and the manufacturer's operating manual. You should qualify on each piece of equipment in your specific work center according to the manufacturer's technical manual and any locally written instruction prior to the setup and operation of any tool or equipment.

As a HT, you will be required to use many different handtools and instruments. Each tool does a specific job. To become a skilled craftsman, you should learn what each tool can do and select the proper tool for the job. The proper use and care of tools enable you to turn out quality work and help you develop safe work habits.

MEASURING AND MARKING TOOLS

The measuring tools found in a shop include various types of rules, calipers, squares, and gauges. They are used to measure lengths, diameters, angles, and radii. *Use and Care of Hand Tools and Measuring Tools,* NAVEDTRA 12085, and *Machinery Repairman,* NAVEDTRA 12204-A, contain more

information on measuring and marking tools. In this section we will cover the use of specialty measuring devices such as torque wrenches, calipers, feeler gauges, metal gauges, and squares.

TORQUE WRENCHES

There are times when, for engineering reasons, a definite force must be applied to a nut or bolt head. In such cases a torque wrench must be used. For example, equal force must be applied to all the head bolts of an engine. Otherwise, one bolt may bear the brunt of the force of internal combustion and ultimately cause engine failure.

The three most commonly used torque wrenches are the deflecting-beam, dial-indicating, and micrometer-setting types (fig. 5-1). When using the deflecting beam and the dial-indicating torque wrenches, the torque is read visually on a dial or scale mounted on the handle of the wrench.

To use the micrometer-setting torque wrench, unlock the grip and adjust the handle to the desired setting on the micrometer-type scale, then relock the grip. Install the required socket or adapter to the square drive of the handle. Place the wrench assembly on the nut or bolt and pull in a clockwise direction with a smooth, steady motion. (A fast or jerky motion will result in an improperly torqued unit.) When the torque applied reaches the torque value, which is indicated on the handle setting, a signal mechanism will automatically issue an audible click, and the handle will release or "break," and move freely for a short distance. The release and free travel is easily felt, so there is no doubt about when the torquing process is complete.

Manufacturers' and technical manuals generally specify the amount of torque to be applied. To assure getting the correct amount of torque on the fasteners, the wrench must be used properly according to manufacturers' instructions.

Use that torque wrench that will read about mid-range for the amount of torque to be applied. BE SURE THAT THE TORQUE WRENCH HAS BEEN CALIBRATED BEFORE YOU USE IT. Remember, too, that the accuracy of torque measuring depends a lot on how the threads are cut and the cleanliness of the threads. Make sure you inspect and clean the threads. If the manufacturer specifies a thread lubricant, it must be used to obtain the most accurate torque reading. When using the deflecting-beam or dial-indicating wrenches, hold the torque at the desired value until the reading is steady.

Torque wrenches are delicate and expensive tools. The following precautions should be observed when using them:

- When using the micrometer-setting type, do not move the setting handle below the lowest torque setting. However, it should be placed at its lowest setting prior to returning to storage.

- Do not use the torque wrench to apply greater amounts of torque than its rated capacity.

- Do not use the torque wrench to break loose bolts that have been previously tightened.

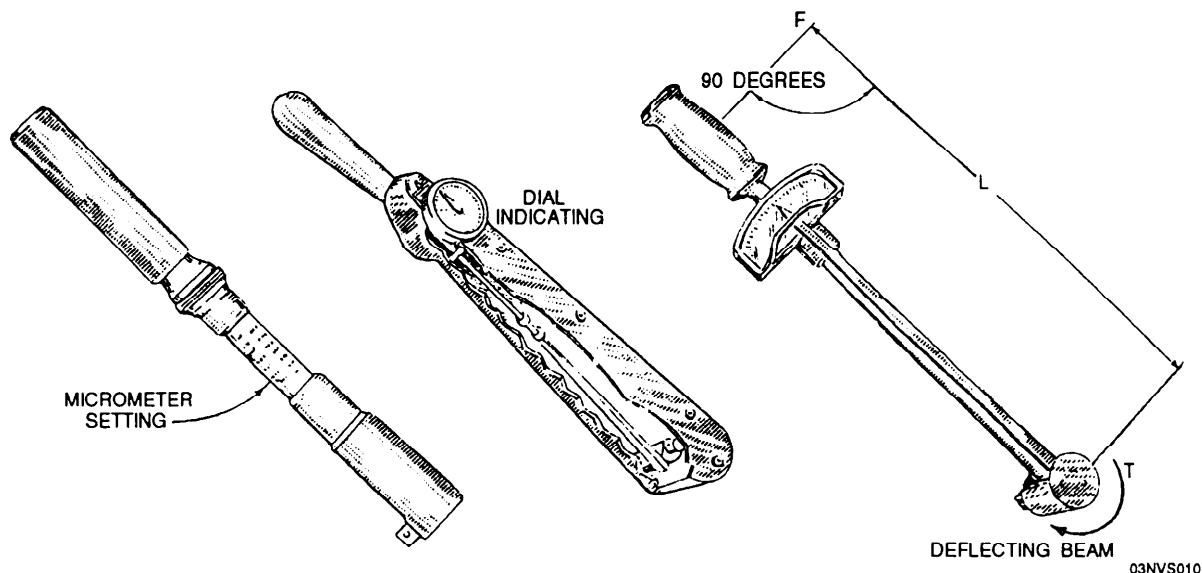- Do not drop the wrench. If dropped, the accuracy will be affected.

Figure 5-1.—Torque wrenches.

● Do not apply a torque wrench to a nut that has been tightened. Back off the nut one turn with a nontorque wrench and retighten to the correct torque with the indicating torque wrench.

● Calibration intervals have been established for all torque tools used in the Navy.

When a tool is calibrated by a qualified calibration activity at a shipyard, tender, or repair ship, a label showing the next calibration due date is attached to the handle. This date should be checked before a torque tool is used to ensure that it is not overdue for calibration.

CALIPERS

Calipers are precision measuring devices that measure length in thousandths of an inch. Calipers differ only in the way they are read and the types of measurements taken. The types of calipers that will be discussed in this chapter are the vernier dial caliper and the vernier.

Vernier Dial Calipers

Vernier dial calipers are the most common type of caliper found in use today. They are preferred over vernier calipers in that they are easier to read and can measure depth. They use a double set of movable and fixed measuring jaws to measure inside and outside measurements as shown in figure 5-2. Depth is measured using a depth gauge rod.

Reading the vernier dial caliper is a relatively simple and easy task involving the addition of the dial reading to the main frame scale reading. It uses a dial marked in thousandths of an inch and a main frame scale marked in inches and hundred-thousandths of an inch. As the dial is drawn across the main frame by an adjustment screw, the reading is registered on the dial face in thousandths of an inch. Before taking your measurement, always zero the dial caliper by aligning the mark on the bezel when the measuring jaws are closed. When you pass the first small numbered mark on the main frame scale, simply add one hundred thousandths to the dial reading. When you pass the first large numbered mark on the main frame scale, add one inch to your dial reading. After passing the first small numbered mark, add one inch one hundred thousandths to the dial reading. Do this wherever the reading falls on the scale.

Vernier Caliper

Vernier calipers are capable of taking measurements to the nearest thousandths of an inch using a stationary and sliding jaw assembly as shown in figure 5-2. Reading the vernier caliper is not as easy as reading the
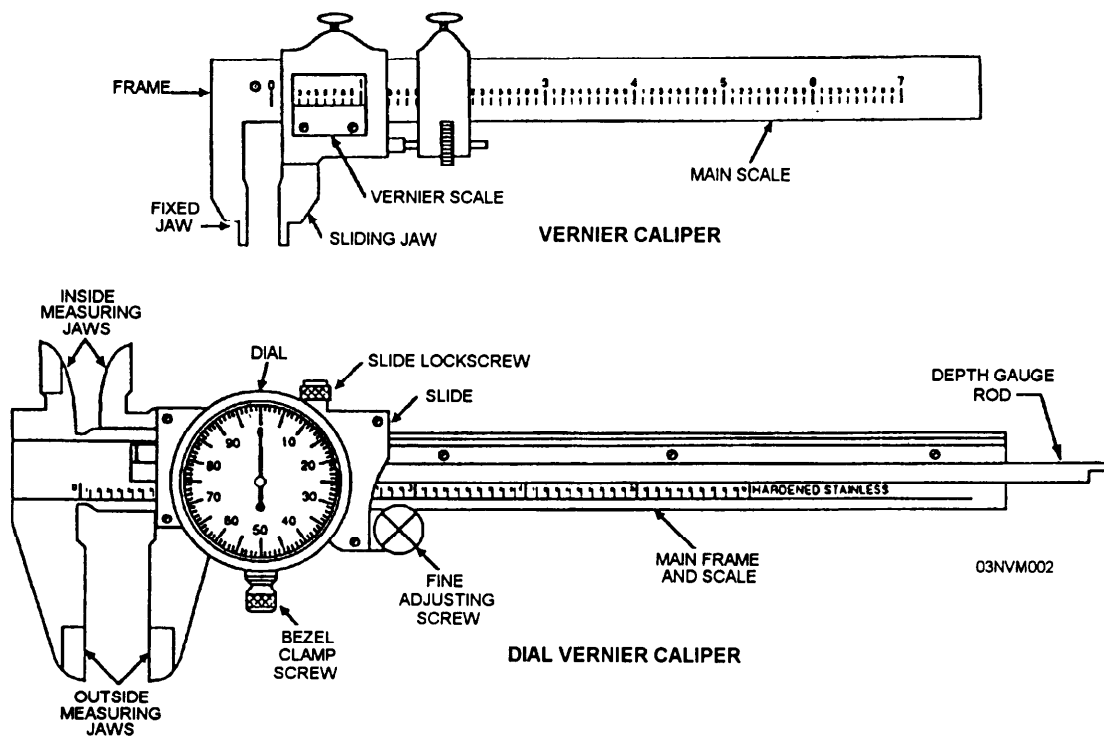

Figure 5-2.—Vernier and vernier dial caliper.

dial caliper (refer to fig. 5-3). The main frame scale (1) is graduated in 0.025 thousandths of an inch. Every fourth division (2) (representing a tenth of an inch) is numbered. The vernier scale (3). on the movable jaw, is divided into 25 parts and numbered 0, 5, 10, 15, 20, and 25. These 25 parts are equal to 24 parts on the main frame scale (1). The difference between the width of one of the 25 spaces on the vernier scale (3) and one of the 24 spaces on the main frame scale (1) is 1/1000 of an inch.

There are five steps to reading the vernier caliper as shown in figure 5-3. They are as follows:

1. Read the number of whole inches on the top scale (1) to the left of the vernier zero index (4) and record as 1.000 inch.

2. Read the number of tenths (5) to the left of the vernier zero index (4) and record as 0.400 inch.

3. Read the number of twenty-fifths (6) between the tenths mark (5) and the vernier zero index (4) and record as 3×0.025 or 0.075 inch.

4. Read the highest line on the vernier scale (3) which lines up with the lines on the top scale (7) and record as 11/25 or 0.011 inch. (Remember, 1/25 = 0.001 inch.)

5. Add the total measurement of the 4 preceding steps to find the total measured length or 1.000 + 0.400 + 0.075 + 0.011 = 1.486 inches.

Vernier calipers only take inside and outside dimensions and cannot take depth readings.

Caliper Maintenance

Since calipers are precision measuring instruments, proper care of the caliper is of great importance. Some of the more important aspects of caliper maintenance are listed as follows:

— Always store the caliper in its carrying case. Never leave calipers on work benches, table tops, weld booths, machinery or equipment, or other areas where the caliper could be knocked off, crushed, bent, or otherwise damaged.

— Calipers should always be calibrated according to the Navy's METCAL program before use.

— Keep the slide and main frame clean and free of dust, dirt, weld splatter, and metal chips.

— Never force the slide. If the slide does not move freely, check for chips or grit on the rack and remove them by cleaning.

GAUGES

There are numerous gauges in use throughout the Navy today. As an HT, you will use numerous gauges to perform your job. This section will discuss various gauges that are used in drilling, tapping, welding, and brazing operations.

Thickness (Feeler) Gauges

Feeler gauges are used for checking and measuring small openings such as root openings and narrow slots found in weld fitups and braze joints. Thickness gauges come in many shapes and sizes, as shown in figure 5-4, and can be made with multiple blades (usually have 2 to 26). Each blade is a specific number of thousandths of an inch thick. This enables the application of one tool to the measurement of a variety of thicknesses. Two or
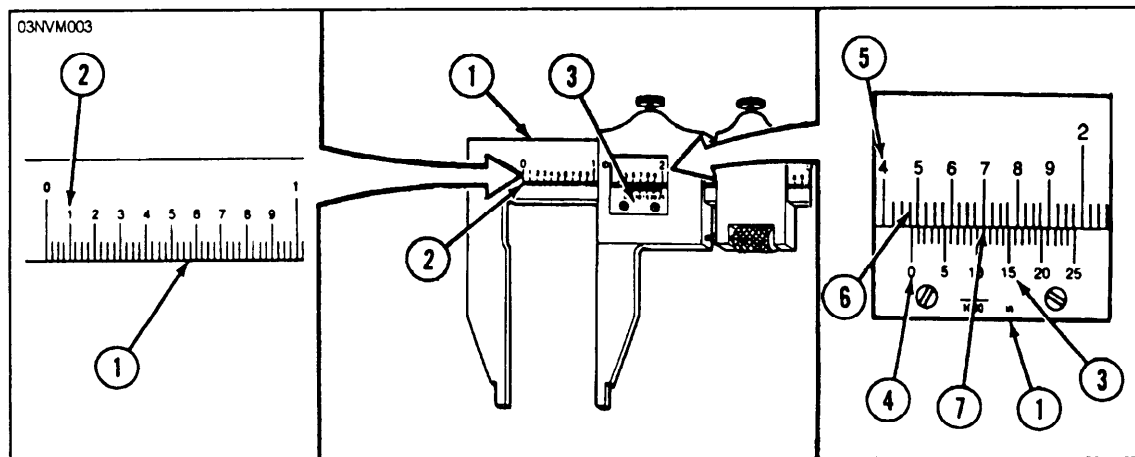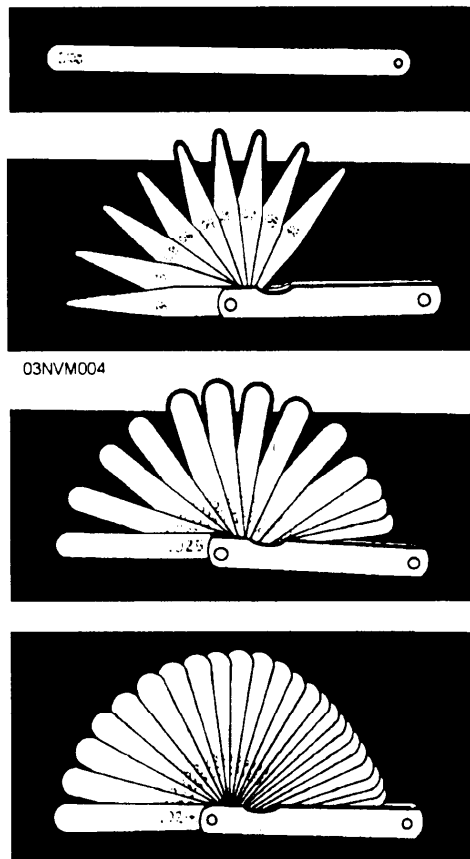

Figure 5-3.—Reading a vernier caliper.

Figure 5-4.—Thickness (feeler) gauges.

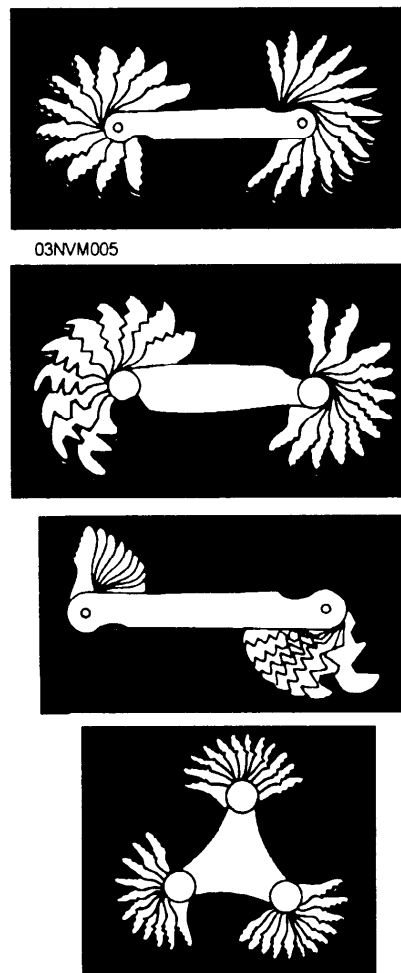**Figure 5-5.—Screw-pitch gauges.**

more blades may be combined to take readings of various thicknesses.

Screw-Pitch Gauges

Screw-pitch gauges (fig. 5-5) are made for checking the pitch of U.S. Standard, Metric, National Form, and V-form cut threads. You will use them to determine the correct thread pitch of an unknown thread on a bolt, inside a nut, or in choosing the correct tap or die for threading stock or tapping a hole. Each thread gauge is marked in number of threads per inch. To take a measurement, simply lay the gauge on the thread. The correct gauge will fit the thread of the bolt perfectly with no light showing between the gauge and the threads of the bolt. The pitch of the screw thread is the distance between the center of one tooth to the center of the next tooth.

Drill Gauges

The twist drill and drill rod gauge has a series of holes with size and decimal equivalents stamped adjacent to each hole, as shown in figure 5-6. Drill gauges use either a letter, number, decimal, or fraction

Figure 5-6.—Drill gauges.

5-5

THICKNESS
OF SHEET

U.S STANDARD
GAUGE FOR
SHEET AND PLATE
IRON AND STEEL
NO 283

03NVM007

GAUGE NO.	BIRMINGHAM WIRE GAUGE (B.W.C.) OR STUBS IRON WIRE GAUGE, FOR IRON WIRES. HOT AND COLD ROLLED SHEET STEEL	AMERICAN WIRE GAUGE, OR BROWN & SHARPE (FOR NON-FERROUS SHEET AND WIRE)	U.S. STANDARD GAUGE FOR SHEET AND PLATE IRON AND STEEL	STEEL WIRE GAUGE, OR THE W & M (WASHBURN & MOEN) FOR STEEL WIRE
0	.340	.3249	.3125	.3085
1	.300	.2893	.2812	.2830
2	.284	.2576	.2656	.2625
3	.259	.2294	.2500	.2437
4	.238	.2043	.2343	.2253
5	.220	.1819	.2187	.2070
6	.203	.1620	.2031	.1920
7	.180	.1443	.1875	.1770
8	.165	.1285	.1718	.1620
9	.148	.1144	.1562	.1483
10	.134	.1019	.1406	.1350
11	.120	.0907	.1250	.1205
12	.109	.0808	.1093	.1055
13	.095	.0719	.0937	.0915
14	.083	.0640	.0781	.0800
15	.072	.0570	.0703	.0720
16	.065	.0508	.0625	.0625
17	.058	.0452	.0562	.0540
18	.049	.0403	.0500	.0475
19	.042	.0359	.0437	.0410
20	.035	.0319	.0375	.0348
21	.032	.0284	.0343	.0317
22	.028	.0253	.0312	.0286
23	.025	.0225	.0281	.0258
24	.022	.0201	.0250	.0230
25	.020	.0179	.0218	.0204
26	.018	.0159	.0187	.0181
27	.016	.0142	.0171	.0173
28	.014	.0126	.0156	.0162
29	.013	.0112	.0140	.0150
30	.012	.0100	.0125	.0140
31	.010	.0089	.0109	.0132
32	.009	.0079	.0101	.0128
33	.008	.0071	.0093	.0118
34	.007	.0063	.0085	.0104
35	.005	.0056	.0078	.0095
36	.004	.0050	.0070	.0090

Figure 5-7.—Steel plate and sheet metal gauges and thicknesses.

to designate drill size. Some drill gauges may use a combination of these designations to measure drill size. You will use these gauges when determining the correct drill size for a given tap size.

Steel Plate and Sheet Metal Gauge

Steel plate and sheet metal gauges come in various sizes and uses, as shown in figure 5-7. You will use them extensively in sheet metal and structural metal fabrication to determine metal thickness or gauge. They are simple to use and extremely accurate. Simply fit the gauge to the plate so that the metal edge slides exactly into the slot. The gauge should be snug, but do not force the gauge onto the metal. Gauge numbers are marked on the front of the gauge with the corresponding decimal reading on the back.

CIRCUMFERENCE RULE

The circumference rule is a specialty rule that is used to figure out the total length of plate needed for manufacturing cylindrical objects. The circumference rule looks similar to a regular steel rule but has two scales marked on its face as shown in figure 5-8. The top scale is an inch scale that is divided in sixteenths of an inch and represents the diameter of an object. The bottom scale is divided in eighths of an inch and represents the circumference of a cylinder. The back of the rule usually has formulas for calculating circumferences and shows areas and tables for laying out measurements.

Reading the circumference rule is a simple process that requires no special math skills. First, determine the diameter of a cylinder in inches. Next, locate the diameter on the top inch scale and read the measurement directly below on the circumference scale to determine the total length of material needed to fabricate the cylinder.

Using figure 5-8 as a guide, let's figure the total length of plate needed to manufacture a 2-inch diameter cylinder. Locate the diameter, or 2 inches, on the top inch scale, then read the circumference rule

Figure 5-8.—Circumference rule.

directly below that mark to get the total length of plate needed to manufacture a 2-inch diameter cylinder or 6 1/4 inches. The total length of plate needed is 6 1/4 inches.

SQUARES

Working in an HT shop, you will use a square almost everyday. Squares are versatile instruments that can be used to lay out lines and angles, to measure distances, and for numerous other functions. There are numerous squares in use today, but only the steel square and the combination square will be discussed in this section.

Steel Square

Steel squares (fig. 5-9) are used to lay out various angles and to check squareness or straightness of an edge or surface. They are L-shaped tools that comes in 12-, 18-, and 24-inch blade length. They are marked in graduations of 1-16- or 1/8-inch divisions on the inside and outside edge. The components of the steel square are as follows:

● BLADE—the longer leg of the square

● TONGUE—the shorter leg of the square

● HEEL—the outside comer

● FACE—the inside edge of the square

● BACK—the outside edge of the blade

When using a steel square to lay out angles, place the tongue of the square on the base line with the 12-inch mark on the vertex of the desired angle. Mark the vertical distance for the desired angle along the blade edge of the square. Connect the vertex to the vertical height mark with a line. Some of the more common angles are shown in figure 5-10.

Combination Square

The combination square (fig. 5-11) is a multifunctional tool that can be used to lay out various angles, measure height and depth, bisect a 90-degree angle, and as a level. It consists of the following components:

— A 12-inch stainless steel rule (1) that is graduated in eighths, sixteenths, thirty-seconds, and sixty-fourths of an inch. The rule is slotted to accept individual tool heads. It can be used as a measuring
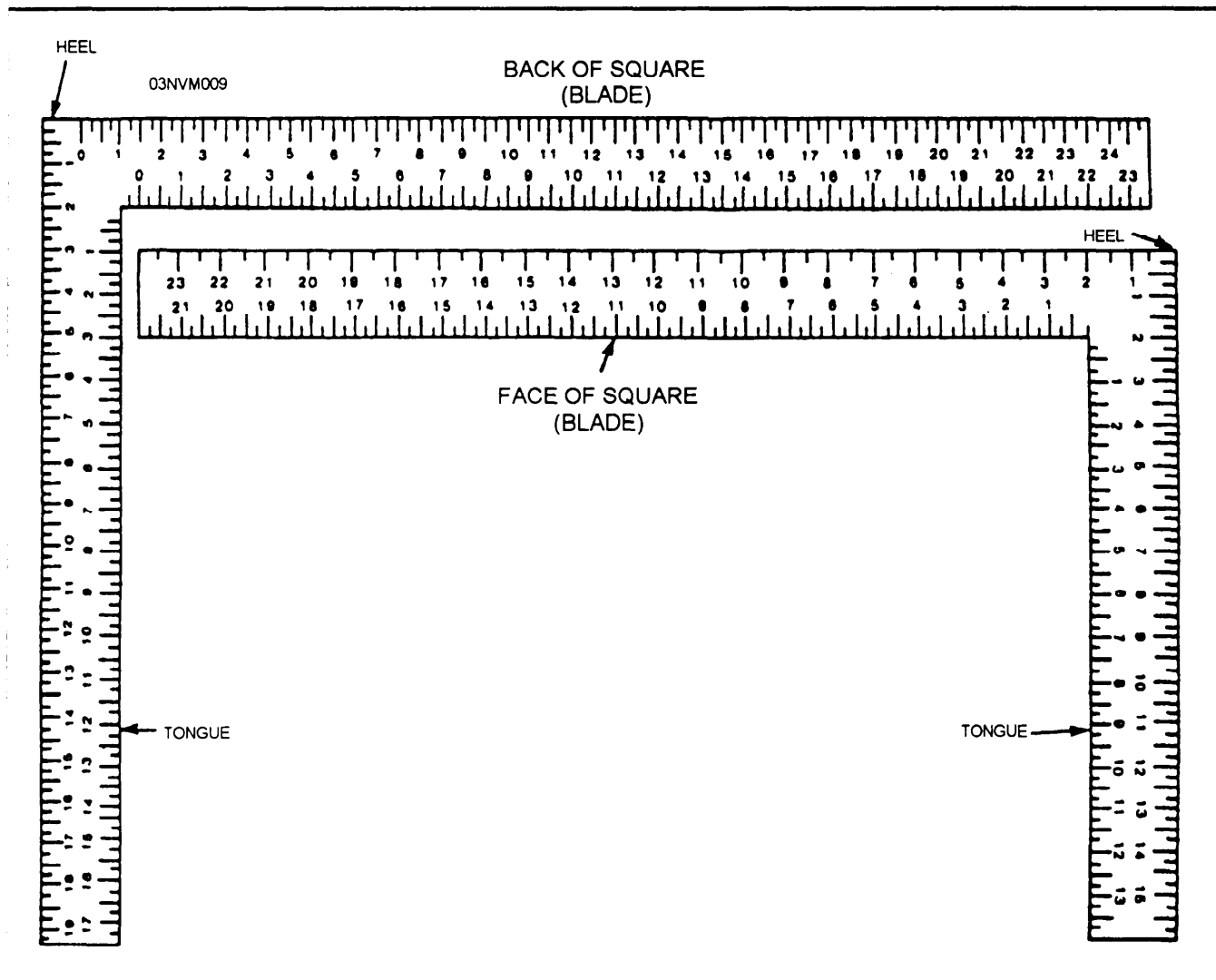
Figure 5-9.—Steel square.

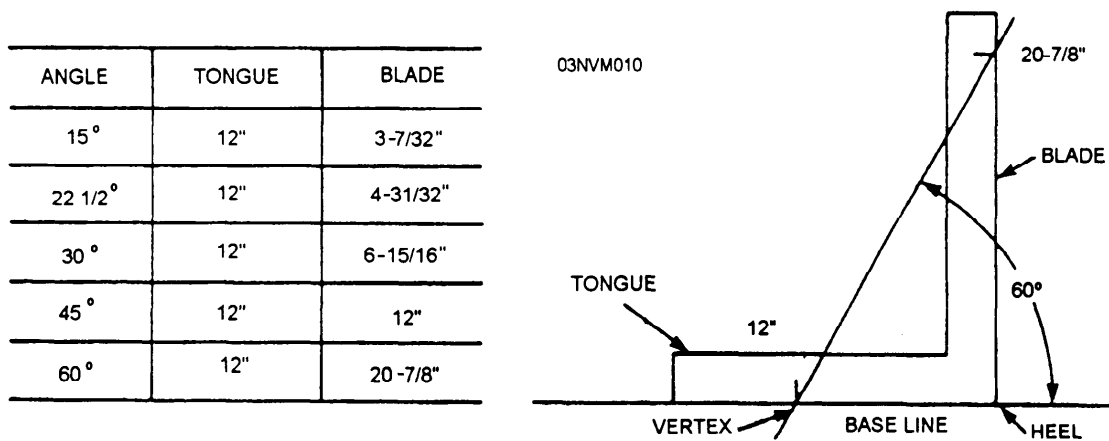| ANGLE	TONGUE	BLADE
15°	12"	3-7/32"
22 1/2°	12"	4-31/32"
30°	12"	6-15/16"
45°	12"	12"
60°	12"	20-7/8"

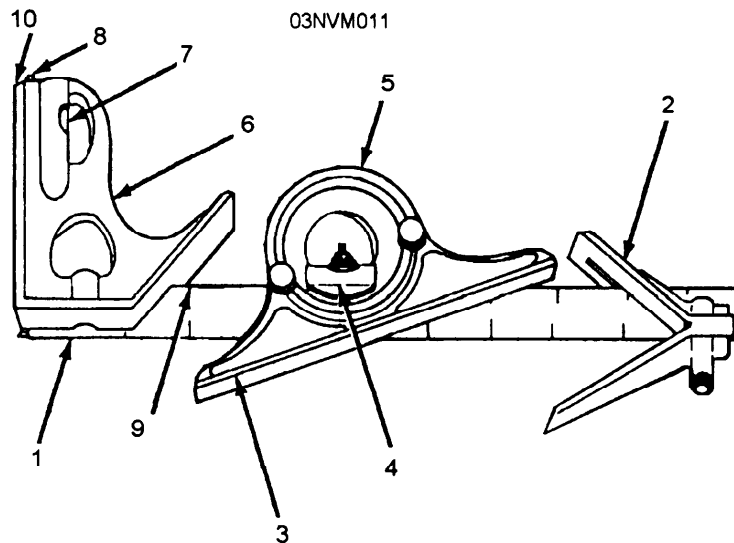**Figure 5-10.—Steel square angle layout.**

Figure 5-11.—Combination square.

scale by itself or with any one of the following components:

— The center head (2), when attached to the slotted rule, bisects a 90-degree angle. It is used to determine the center of a cylindrical object.

— The protractor head (3) has a level (4) and a revolving turret (5) that is graduated in degrees from 0 to 180 or 0 to 90 in either direction. It is used to lay out and measure angles to within one degree.

— The square head (6) has a level (7), scribe (8), and 45- (9) and 90-degree sides (10). When it is attached to the slotted steel rule, it can be used to lay out 45- and 90-degree angles and to check level. The square head may also be used as a height or depth gauge.

TRAMMELS

Trammels (fig. 5-12) measure distances beyond the range of calipers. They also can be used as calipers, if you have the auxiliary attachments.

The basic trammel consists of two heads (trams). One head has a device for fine adjustments. The wooden beam must be made by the HT as it is not provided by the manufacturer. You can attach divider points, caliper legs, and ball points to the tram. The ball points with holder are used for scribing or measuring from the center of a hole.

Figure 5-12.—Trammels.

5-9

A. AUGER BIT

03NVM013

B. EXPANSION BIT

C. TWIST DRILL

D. FORSTNER BIT

E. MACHINE SPUR BIT

F. MULTISPUR BIT

Figure 5-13.—Drill bits.

Figure 5-14.—Parts of an auger bit.
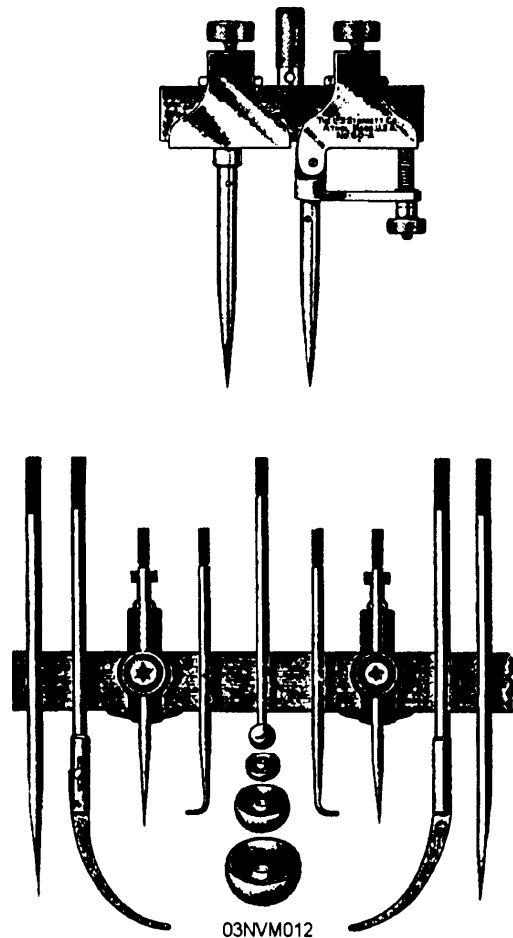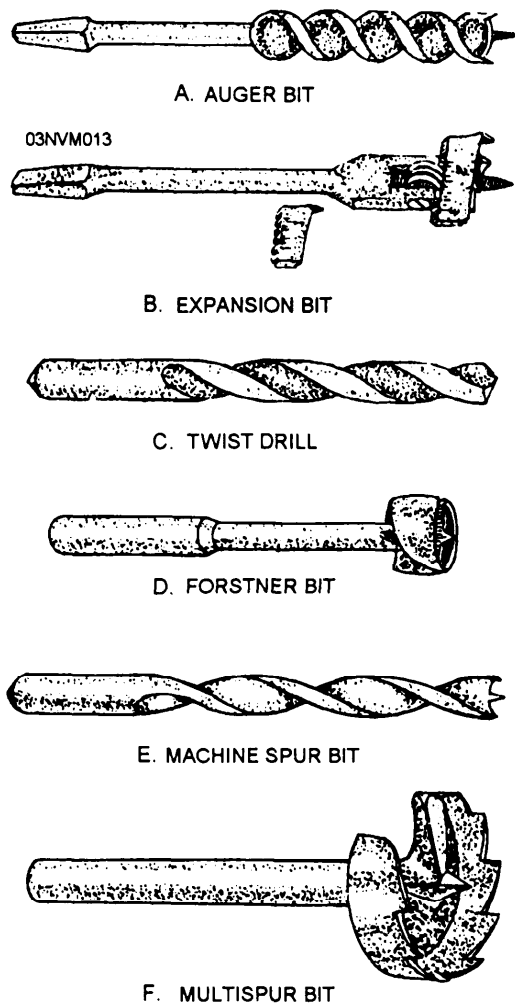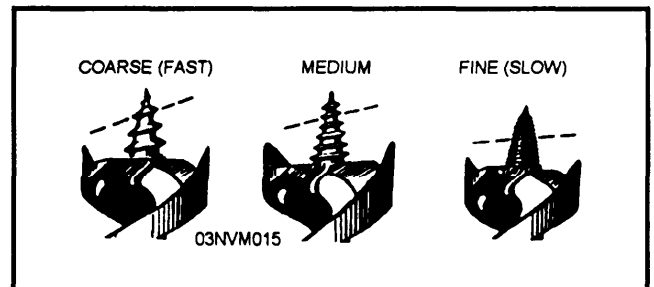
Figure 5-15.—Types of screw points.

WOOD- AND METAL-BORING BITS

The wood-boring bits and drills usually found in the HT shop are shown in figure 5-13—included are the auger bit, expansion bit, twist bit, machine spur bit, and multispur bit.

AUGER BIT

The auger bit (fig. 5-13, view A) is the most common of the wood-boring bits. It should be used with a hand brace. It consists of three parts: the head, twist, and shank, as shown in figure 5-14.

The screw point functions to center the bit and to pull the bit through the stock. The three types of screw points are coarse, medium, and fine (fig. 5-15). The coarse bit is drawn through the stock faster than a fine one, but there is more roughness because of the faster cut.

The spurs function to score the outer edge of the chip as the cutting lips chisel or cut the waste material loose. The spurs and cutting lips must be sharp to produce a smooth hole.

The twist of the auger bit is responsible for removing waste material after being cut by the spurs and cutting lips. It is slightly smaller in diameter than the head. The twist comes in three styles—single twist with solid center, single twist, and double twist.

● The single twist with solid center clears chips more rapidly, is stronger, and is more common than the single or double twist.

● The single twist has less tendency to bind in certain materials but is more fragile than the single twist with solid center.

● The double twist produces a clean, smooth, accurate hole and bores slower than other twist bits. It is the most suitable of the three to bore holes for wooden dowels.

The shank is that part of the auger bit that fits into the chuck of the brace. It has the drill size number stamped on one of the flats of the square-tapered tang. This number represents the drill size in sixteenths of an inch (fig. 5-16). For instance, if the number stamped on the flat is 12, the drill size is 12/16 inch or 3/4 inch. All bits having a tang-type shank are numbered and sized in this manner.

Auger bits usually come in sets containing 1/4-inch (#4) to 1-inch (#16) bits, but they are available up to 2 inches (#32) in diameter. Many different lengths of auger bits are available and come in three sizes. The dowel bit is about 5 inches long. The medium bit is about 8 inches long and the ship bit is from 18 to 24 inches long. The medium bit is the length most commonly used.

EXPANSION BIT

Another bit designed for use with the brace and to bore holes larger than 7/8 inch is the expansion, or
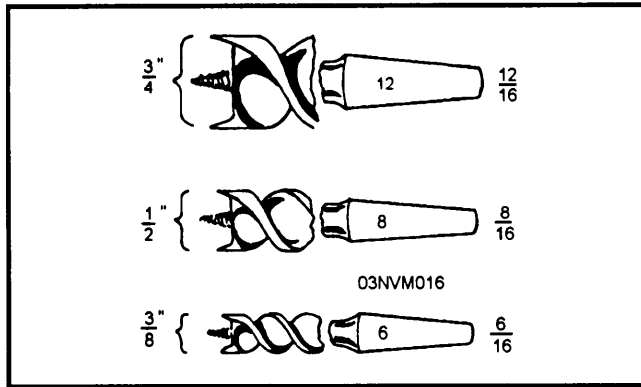
Figure 5-16.—Size markings on auger bits.
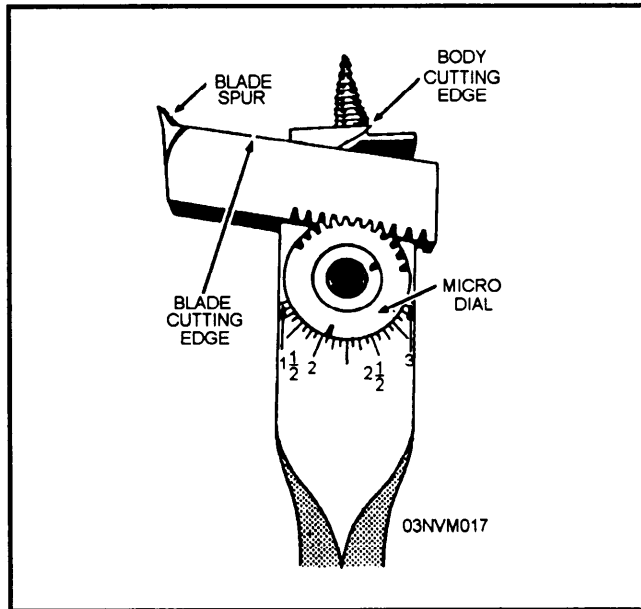
Figure 5-17.—Expansion bit.

expansive, bit (fig. 5-17). The expansion bit consists of a screw point, the body cutting edge, and three adjustable cutter blades. The blades let you bore holes up to 4 inches in diameter. The adjustable cutter blade adjusts by either a microdial (fig. 5-17) or a simple screw arrangement. Make a trial cut on scrap stock after adjusting an expansion bit to make sure that the bit is cutting the exact diameter desired.

TWIST BIT

The twist drill bit (fig. 5-13, view C) is used to bore holes 1/2 inch and under. They work with any type of drill. High-carbon or high-speed steel twist drills are used for low-speed metal boring or high-speed wood boring. The high-speed steel drill is for high-speed metal boring.

Twist drills come in several styles. The styles are differentiated by the shank. The part of the twist drill that fits into the socket, spindle, or chuck of the drill press is known as the shank. The three most common types of shanks are shown in figure 5-18.
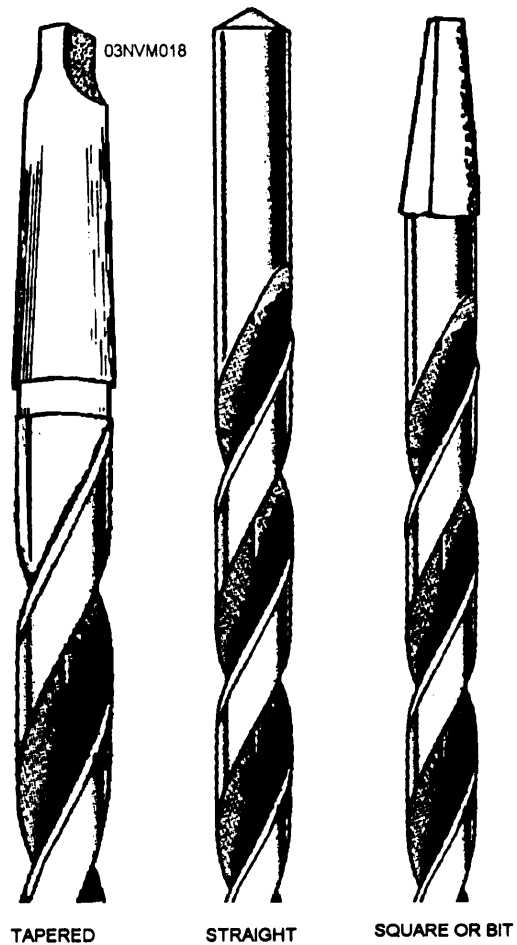

Figure 5-18.—Three most common types of shanks.

5-11

Table 5-1.—Twist Drill Sizes

SIZE	DECIMAL EQUIVALENTS	SIZE	DECIMAL EQUIVALENTS	SIZE	DECIMAL EQUIVALENTS
1/2	0.5000	C	0.2420	30	0.1285
31/64	.4844	B	.2380	1/8	.1250
15/32	.4687	15/64	.2344	31	.1200
10/64	.4531	A	.2340	32	.1160
7/16	.4375	No. 1	.2280	33	.1130
27/64	.4219	2	.2210	34	.1110
Z	.4130	7/32	.2187	35	.1100
13/32	.4062	3	.2130	7/64	.1094
Y	.4040	4	.2090	36	.1065
X	.3970	5	.2055	37	.1040
25/64	.3906	6	.2040	38	.1015
W	.3860	13/64	.2031	39	.0995
V	.3770	7	.2010	40	.0980
3/8	.3750	8	.1990	41	.0960
U	.3680	9	.1960	3/32	.0937
23/64	.3594	10	.1935	42	.0935
T	.3580	11	.1910	43	.0890
S	.3480	12	.1890	44	.0860
11/32	.3437	3/16	.1875	45	.0820
R	.3390	13	.1850	46	.0810
Q	.3320	14	.1820	47	.0785
21/64	.3281	15	.1800	5/64	.0781
P	.3230	16	.1770	48	.0760
O	.3160	17	.1730	49	.0730
5/16	.3125	11/64	.1719	50	.0700
N	3020	18	.1695	51	.0670
12/64	2969	19	.1660	52	.0635
M	.2950	20	.1610	1/16	.0625
L	.2900	21	.1590	53	.0595
7/32	.2812	22	.1570	54	.0550
K	.2810	5/32	.1562	55	.0520
J	.2770	23	.1540	3/64	.0469
I	.2720	24	.1520	56	.0465
H	.2660	25	.1495	57	.0430
17/64	.2656	26	.1470	58	.0420
G	.2610	27	.1440	59	.0410
F	.2570	9/64	.1406	60	.0400
E 1/4	.2500	28	.1405		
D	.2460	29	.1360		

Twist drills have various shank types sized by fraction, number, or letter. Fraction symbols give the actual size of the drill. Sets that include sizes from 1/16 to 1/2 inch are common in the shop. Number and letter designators only identify the drill. A drill gauge or reference chart (table 5-1) gives the actual size of the drill. Note that the letter sizes are larger and start where the number sizes stop. The most common type used in HT shops is the carbon steel drill with a straight shank.

A drill should be reground at the first sign of dullness. The increased load that dullness imposes on the cutting edges may cause a drill to break.

Twist drills are sharpened differently for boring different materials. The two common angles are the regular point (fig. 5-19) and the flat point (fig. 5-20). The regular point has an angle of 118° and is used for general boring, which includes wood and metal. The flat point has an angle of 135° and is used to bore hard and tough materials.

The general-purpose twist drill is made of high-speed steel. Figure 5-21 shows a typical plastic-cutting drill and a typical metal-cutting drill. Notice the smaller angle on the drill used for drilling plastics.

Before putting a drill away, wipe it clean and give it a light coating of oil. Do not leave drills in a place where they may be dropped or where heavy objects
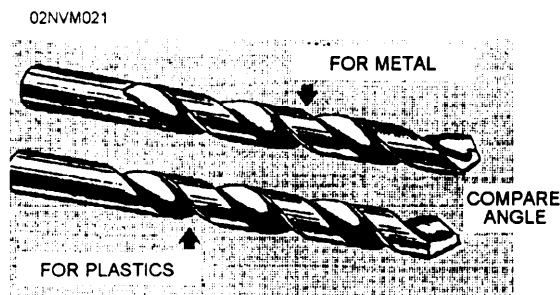
Figure 5-21.—Comparison of a twist drill for plastic and a twist drill for metal.

may fall on them. Do not place drills where they will rub against each other.

MACHINE SPUR BIT

The machine spur bit (fig. 5-13, view E) works only in a drill press. It is a high-speed, smooth-cutting bit for boring deep, flat-bottomed holes. It has a centering point and a twist to remove waste material and comes in sizes ranging from 1/8 to 1/2 inch in diameter.

MULTISPUR BIT

The multispur bit (fig. 5-13, view F) also works strictly in drill presses. Use it to bore flat-bottomed holes larger than the machine spur bit and ranges in size from 1/2 to 4 inches in diameter.

NOTE: As bit sizes increase, drill press speed decreases.

COUNTERSINKS

The countersink forms a seat for the head of a flat-headed wood screw and comes in three types (fig. 5-22). Type A is for use with a hand brace. Types B
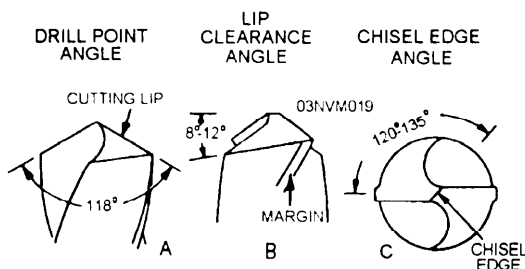

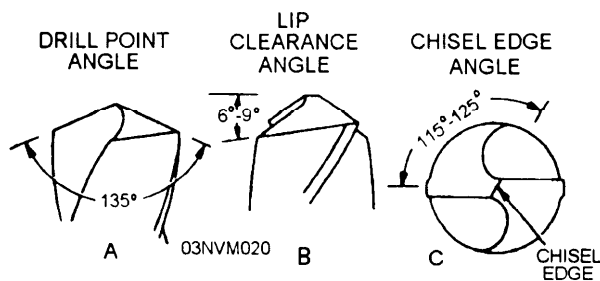Figure 5-19—Specifications for grinding a regular point twist drill.

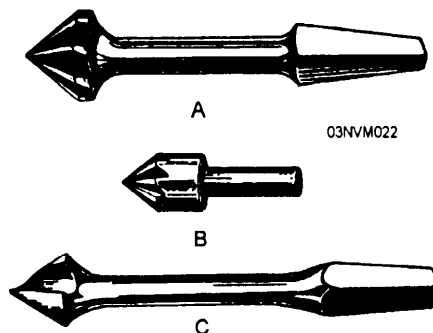Figure 5-20.—Specifications for grinding a flat point twist drill.

Figure 5-22.—Types of countersinks.

5-13

and C are used in either the hand drill, portable electric drill, or drill press. Type B produces a rough surface but cuts the fastest. Type C produces a smooth seat and is the countersink of choice for finish work.

There are many types of combination counter-sinks and counterbores, but they all perform the same function. These tools make the pilot hole, shank clearance, and countersink in one operation. The combination counterbore performs the same tasks as the combination countersink and bores a plug hole for wooden plugs. Combination countersinks and counterbores range in size from #6 to #12 and accommodate wood screw sizes #5 to #14.

The particular size of wood screw each counter-sink and counterbore accommodates determines the size of the countersink or counterbore. Use both with the hand drill, portable electric drill, and drill press.

Figure 5-23.—Types of points on the metal-cutting chisel.

METAL-CUTTING TOOLS

There are many types of metal-cutting tools used by skilled mechanics of all ratings. As you become better acquainted with your rating, you will probably discover many tools that you use for cutting metal that are not described in this chapter. In this chapter, only the basic hand metal-cutting tools (chisels, hacksaws, and files) will be discussed due to their frequent but incorrect use.

CHISELS

Chisels are tools that can be used for chipping or cutting metal. They will cut any metal that is softer than the materials of which they are made. Chisels are made from a good grade tool steel and have a hardened cutting edge and beveled head. Cold chisels are classified according to the shape of their points, and the width of the cutting edge denotes their size. The most common shapes of chisels are flat (cold chisel), cape, round nose, and diamond point (fig. 5-23).

The type of chisel most commonly used is the flat cold chisel that cut rivets, split nuts, chip castings, and cut thin metal sheets. The cape chisel is used for special jobs like cutting keyways, narrow grooves, and square corners. Round-nose chisels make circular grooves and chip inside corners with a fillet. Finally, the diamond-point is used for cutting V-grooves and sharp corners.

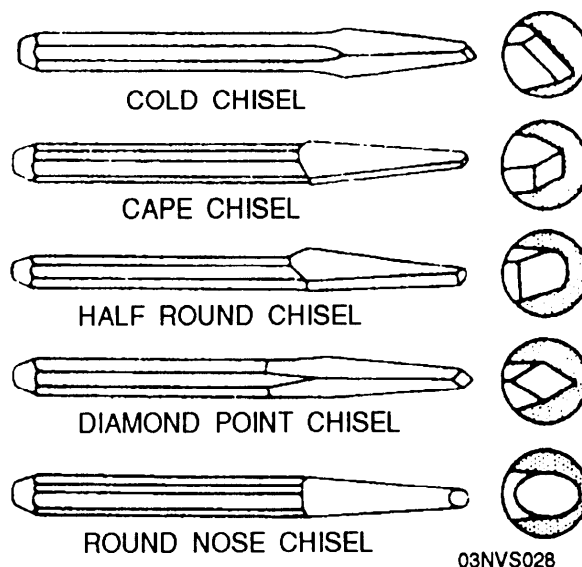As with other tools, there is a correct technique for using a chisel. Select a chisel that is large enough for the job. Be sure to use a hammer that matches the chisel; that is, the larger the chisel, the heavier the hammer. A heavy chisel will absorb the blows of a light hammer and will do virtually no cutting. As a general rule, you should hold the chisel in your left hand with the thumb and first finger about 1 inch from the top. You should hold it steady but not tight. Your finger muscles should be relaxed, so if the hammer strikes your hand it will permit your hand to slide down the tool and lessen the effect of the blow. Keep your eyes on the cutting edge of the chisel, not on the head, and swing the hammer in the same plane as the body of the chisel. If you have a lot of chiseling to do, slide a piece of rubber hose over the chisel. This will lessen the shock to your hand.

When using a chisel for chipping, always wear goggles to protect your eyes. If other people are working close by, see that they are protected from flying chips by erecting a screen or shield to contain the chips. Remember that the time to take these precautions is before you start the job.

After numerous blows to the head of a chisel, it will begin to deform. This deformation is called mushrooming and creates a very dangerous situation. If the head of a chisel mushrooms excessively, bits of the head will begin to fly off when struck with a hammer. These small bits of metal have the force of shrapnel from a hand grenade and could cause as much damage. Simply keep the head of a chisel ground down to remove this dangerous situation.

FILES

A tool kit for nearly every rating in the Navy is not complete unless it contains an assortment of files. There are a number of different types of files in common use, and each type may range in length from 3 to 18 inches.

Files and rasps fall into the abrading tool family. You only need the half-round file and the half-round rasp for ordinary work. The most useful sizes are 6, 8, and 10 inches.

Grades

Files are graded according to the degree of fineness, and according to whether they have single- or double-cut teeth. The difference is apparent when you compare the files in figure 5-24, view A.

Single-cut files have rows of teeth cut parallel to each other. These teeth are set at an angle of about 65 degrees with the center line. You will use single-cut files for sharpening tools, finish filing, and draw filing. They are also the best tools for smoothing the edges of sheet metal.

Files with crisscrossed rows of teeth are double-cut files. The double cut forms teeth that are diamond-shaped and fast cutting. You will use double-cut files for quick removal of metal and for rough work.

Files are also graded according to the spacing and size of their teeth, or their coarseness and fineness. Some of these grades are pictured in figure 5-24, view B. In addition to the three grades shown, you may use some DEAD SMOOTH files, which have very fine teeth, and some ROUGH files with very coarse teeth. The fineness or coarseness of file teeth is also influenced by the length of the file. (The length of a file is the distance from the tip to the heel, and does not include the tang (fig. 5-24, view C). When you have a chance, compare the actual size of the teeth of a 6-inch, single-cut smooth file and a 12-inch, single-cut smooth file; you will notice the 6-inch file has more teeth per inch than the 12-inch file.
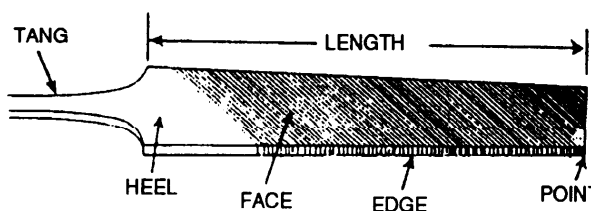
Shapes

Files come in different shapes. Therefore, in selecting a file for a job, the shape of the finished work must be considered. Some of the cross-sectional shapes are shown in figure 5-24, view D.
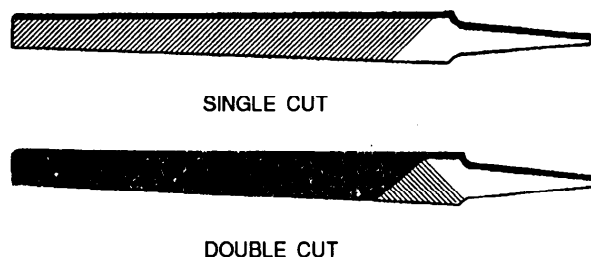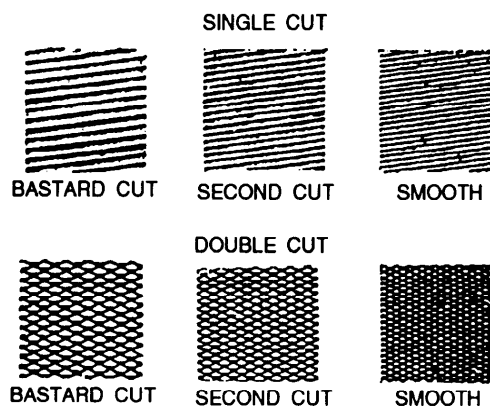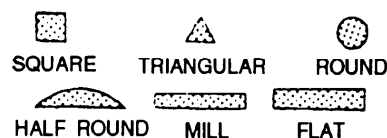

Figure 5-24.—File information.

TRIANGULAR files are tapered (longitudinally) on all three sides. They are used to file acute internal angles and to clear out square corners. Special triangular files are used to file saw teeth.

MILL files are tapered in both width and thickness. One edge has no teeth and is known as a

safe edge. Mill files are used for smoothing lathe work draw filing, and other fine, precision work. Mill files are always single-cut.

FLAT files are general-purpose files and may be either single- or double-cut. They are tapered in width and thickness. HARD files, not shown, are somewhat thicker than flat files. They taper slightly in thickness, but their edges are parallel. The flat or hard files most often used are the double-cut for rough work, and the single-cut, smooth file for finish work.

SQUARE files are tapered on all four sides and are used to enlarge rectangular-shaped holes and slots.

ROUND files serve the same purpose for round openings. Small round files are often called "rattail" files.

The HALF-ROUND file is a general-purpose tool. The rounded side is used for curved surfaces and the flat face on flat surfaces. When you file an inside curve, use a round or half-round file whose curve most nearly matches the curve of the work.

Care of Files

You should break in a new file carefully by using it first on brass, bronze, or smooth cast iron. Just a few of the teeth will cut at first, so use a light pressure to prevent tooth breakage. Do not break in a new file by using it first on a narrow surface. Protect the file teeth by hanging your files in a rack when they are not in use, or by placing them in drawers with wooden partitions. Your files should not be allowed to rust—keep them away from water and moisture. Avoid getting the files oily. Oil causes a file to slide across the work and prevents fast, clean cutting. Files that you keep in your toolbox should be wrapped in paper or cloth to protect their teeth and prevent damage to other tools.

HACKSAWS

Hacksaws are used to cut metal that is too heavy for snips or bolt cutters. Thus, metal bar stock can be cut readily with hacksaws.

There are two parts to a hacksaw: the frame and the blade. Common hacksaws have either an adjustable or solid frame (fig. 5-25). Most hacksaws found in the Navy are of the adjustable frame type. Adjustable frames can be made to hold blades from 8 to 16 inches long, while those with solid frames take only the length blade for which they are made. This
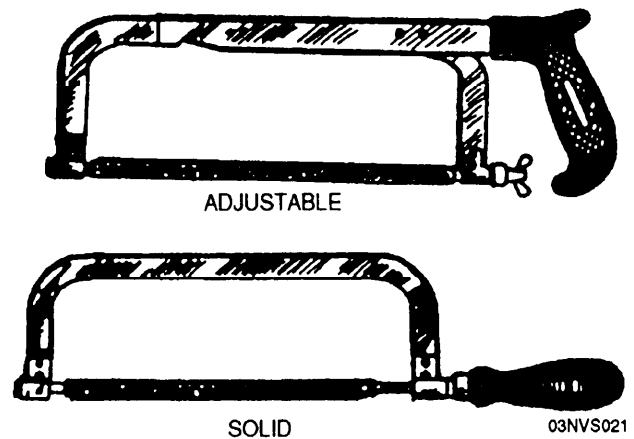

Figure 5-25.—Hacksaws.

length is the distance between the two pins that hold the blade in place.

Hacksaw blades are made of high-grade tool steel, hardened and tempered. There are two types: the all-hard and the flexible. All-hard blades are hardened throughout, whereas only the teeth of the flexible blades are hardened. Hacksaw blades are about one-half inch wide, have from 14 to 32 teeth per inch, and are from 8 to 16 inches long. The blades have a hole at each end that hooks to a pin in the frame. All hacksaw frames that hold the blades either parallel or at right angles to the frame are provided with a wingnut or screw to permit tightening or removing the blade.

The SET in a saw refers to how much the teeth are pushed out in opposite directions from the sides of the blade. The four different kinds of set are ALTERNATE set, DOUBLE ALTERNATE set, RAKER set, and WAVE set. Three of these are shown in figure 5-26.

The teeth in the alternate set are staggered, one to the left and one to the right throughout the length of the blade. On the double alternate set blade, two
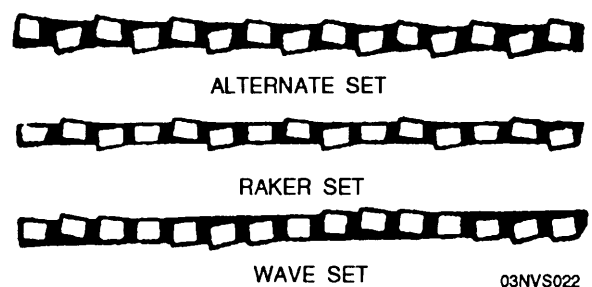

Figure 5-26.—"Set" of hacksaw blade teeth.

5-16

adjoining teeth are staggered to the right, two to the left, and so on. On the raker set blade, every third tooth remains straight and the other two are set alternately. On the wave (undulated) set blade, short sections of teeth are bent in opposite directions.

Using Hacksaws

The hacksaw is often used improperly. Although it can be used with limited success by an inexperienced person, a little thought and study given to its proper use will result in faster and better work and less dulling and breaking of blades.

Good work with a hacksaw depends not only upon the proper use of the saw, but also upon the proper selection of the blades for the work to be done. Figure 5-27 will help you select the proper blade to use when sawing metal with a hacksaw. Coarse blades with fewer teeth per inch cut faster and are less liable to choke up with chips. However, finer blades with more teeth per inch are necessary when thin sections are being cut. The selection should be made so that, as each tooth starts its cut, the tooth ahead of it will still be cutting.

To make the cut, first install the blade in the hacksaw frame (fig. 5-28) so that the teeth point away
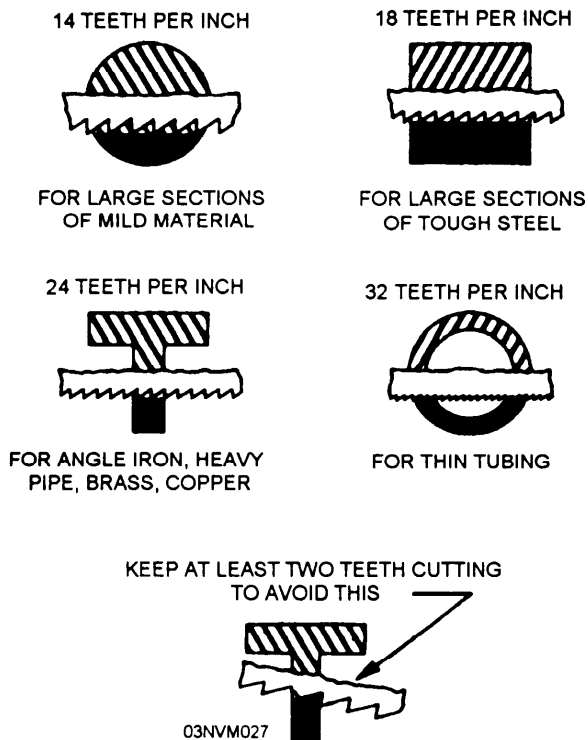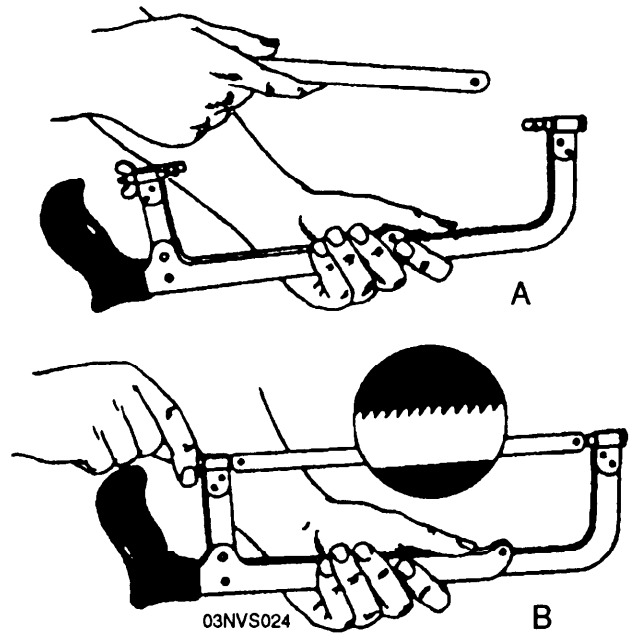

Figure 5-28.—Installing a hacksaw blade.

from the handle of the hacksaw (hand hacksaws cut on the push stroke.) Tighten the wingnut so that the blade is definitely under tension. This helps make straight cuts.

Place the material to be cut in a vise. A minimum of overhang will reduce vibration, give a better cut, and lengthen the life of the blade. Have the layout line outside of the vise jaw so that the line is visible while you work.

When cutting, apply pressure on the forward stroke, which is the cutting stroke, but not on the return stroke. From 40 to 50 strokes per minute is the usual speed. Long, slow, steady strokes are preferred.

For long cuts (fig. 5-29) rotate the blade in the frame so that the length of the cut is not limited by the depth of the frame. Hold the work with the layout line close to the vise jaws, raising the work in the vise as the sawing proceeds.
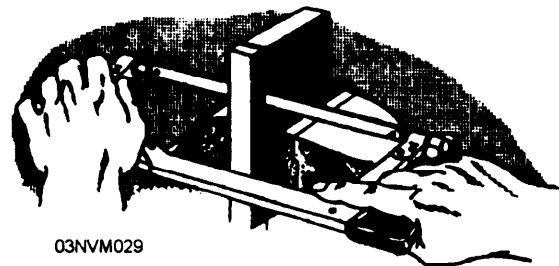

14 TEETH PER INCH

FOR LARGE SECTIONS OF MILD MATERIAL

18 TEETH PER INCH

FOR LARGE SECTIONS OF TOUGH STEEL

24 TEETH PER INCH

FOR ANGLE IRON, HEAVY PIPE, BRASS, COPPER

32 TEETH PER INCH

FOR THIN TUBING

KEEP AT LEAST TWO TEETH CUTTING TO AVOID THIS

03NVM027

Figure 5-27.—Selecting the proper hacksaw blade.

Figure 5-29.—Making a long cut near the edge of stock.

5-17

Saw thin metal as shown in figure 5-30. Notice the long angle at which the blade enters the saw groove (kerf). This permits several teeth to be cutting at the same time.

Metal that is too thin to be held, as shown in figure 5-31, can be placed between blocks of wood, as shown in figure 5-3 1. The wood provides support for several teeth as they are cutting. Without the wood, as shown in view B of figure 5-31, teeth will be broken due to excessive vibration of the stock and because individual teeth have to absorb the full power of the stroke.

Cut thin metal with layout lines on the face by using a piece of wood behind it (fig. 5-32). Hold the wood and the metal in the jaws of the vise, using a
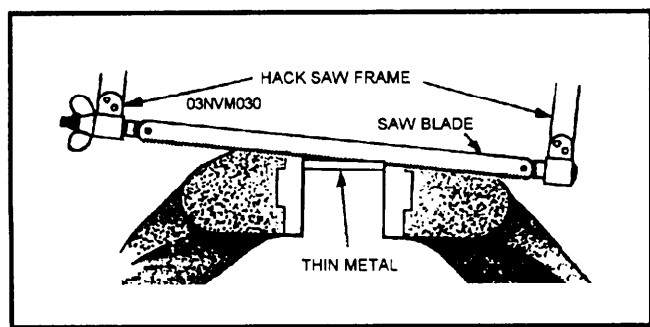

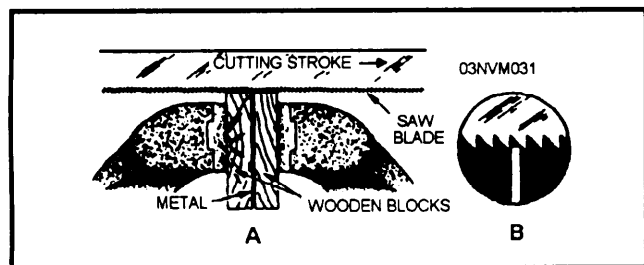**Figure 5-30.—Gutting thin metal with a hacksaw.**

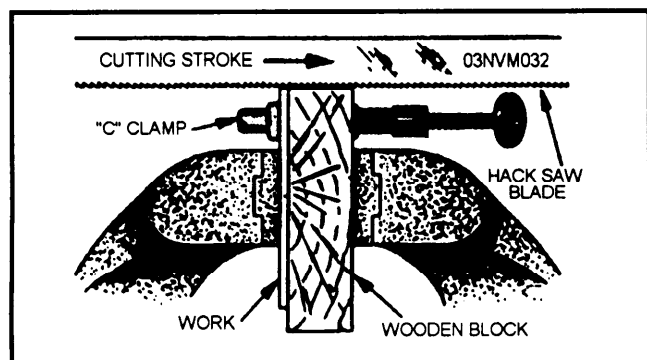**Figure 5-31.—Cutting thin metal between two wooden blocks.**

Figure 5-32.—Gutting thin metal using wood block with layout lines.

C-clamp when necessary. The wood block helps support the blade and produces a smoother cut. Using the wood only in back of the metal permits the layout lines to be seen.

Hacksaw Safety

The main danger in using hacksaws is injury to your hand if the blade breaks. The blade will break if too much pressure is applied, when the saw is twisted, when the cutting speed is too fast, or when the blade becomes loose in the frame. Additionally, if the work is not tight in the vise, it will sometimes slip, twisting the blade enough to break it.

PORTABLE POWER HANDTOOLS

You will be using portable power drills, hammers, and grinders in the shop and out on the job. You should be thoroughly familiar with the operation and care of these tools and with applicable safety precautions. Individual electrically powered hand tools are not covered in this chapter. However, it is important that you understand some important safety and operating procedures for these tools. Only the most common portable pneumatic power tools will be covered in this chapter.

Most portable power tools are driven by electricity. However, the portable power tools that you use may be powered by electric motors or by air (pneumatic) motors. Whether electric powered or air powered, the tools and the procedures for using them are basically the same. Maintenance information about portable power tools can be found in the equipment owner' s manual.

ELECTRICAL POWER TOOLS

Several safety and operating precautions must be observed when you use electrical tools. The most important of these relate to electrical shock. Electrical tools are made so all current-carrying parts, except filters, are insulated from housings and handles. The tools are laboratory tested to ensure they are safe to use when new. However, tool abuse (overload or dropping) could cause a short and you could receive an electrical shock. You can reduce the electrical shock hazard by ensuring that there is a grounding wire between the tool housing and a positive ground.

All electrically powered tools must have a three-wire cord and be double-insulated. All

electrically powered hand tools are required to be stored in the electrical tool issue room so that they may be checked by an electrician prior to issue. Never use a portable electric tool that has not been electrically safety checked by shipboard electricians. Always follow approved checkout procedures for electrical tools. A 120-volt shock can kill you.

Many portable tool housings are made of special high-impact plastic that is resistant to damage. Plastic reduces the electrical shock hazard, but it does not prevent shock hazards completely. To eliminate this shock hazard when using electrically powered tools, you should wear approved electrical rubber gloves (issued with the tool by the electrician). These rubber gloves should be protected with a pair of leather gloves over them. Other safety precautions are listed as follows:

- When using an electric tool, make sure it is properly grounded. Use only three-wire grounded cords and plugs.

- When an extension cord must be used in addition to the cord on an electric tool, the extension cord must not be energized when the tool plug is inserted in or removed from the extension cord. Extension cords also must have three-wire cords and grounded plugs. Extension cords may only be 25 feet in length for shipboard use.

- All portable electrical tools and extension cords require a periodic safety check for shorts or grounds. The tool housing, cord, and plug should be checked for real or potential damage before each use.

- Ensure work is properly secured prior to operating portable equipment.

PNEUMATIC POWER TOOLS

This section deals with pneumatic drills and pneumatic grinders since these are probably the most widely used portable power tools. You will be required to maintain the portable pneumatic tools that you will be using.

Since pneumatic tools use compressed air, all low-pressure compressed air systems should have a filter, regulator, and lubricator assembly installed at the outlet. This assembly will ensure delivery of clean, regulated, mist-lubricated compressed air for the operation of pneumatic tools. The pressure must not exceed 90 psi for any pneumatic tool. **CAUTION:** Never point the air hose at another person.

Before operating a pneumatic drill, inspect the air hose and check for any leaks and damage. Blow air through the air hose to free it of foreign material before connecting it to the drill. Keep the air hoses clean and free from excessive amounts of lubricants.

The heavy duty pneumatic drill, shown in view A of figure 5-33, is reversible. Its speed can be closely controlled by the throttle valve located in the handle. The variable speed feature of this drill makes it particularly useful for heavy duty drilling in places that are hard to reach.
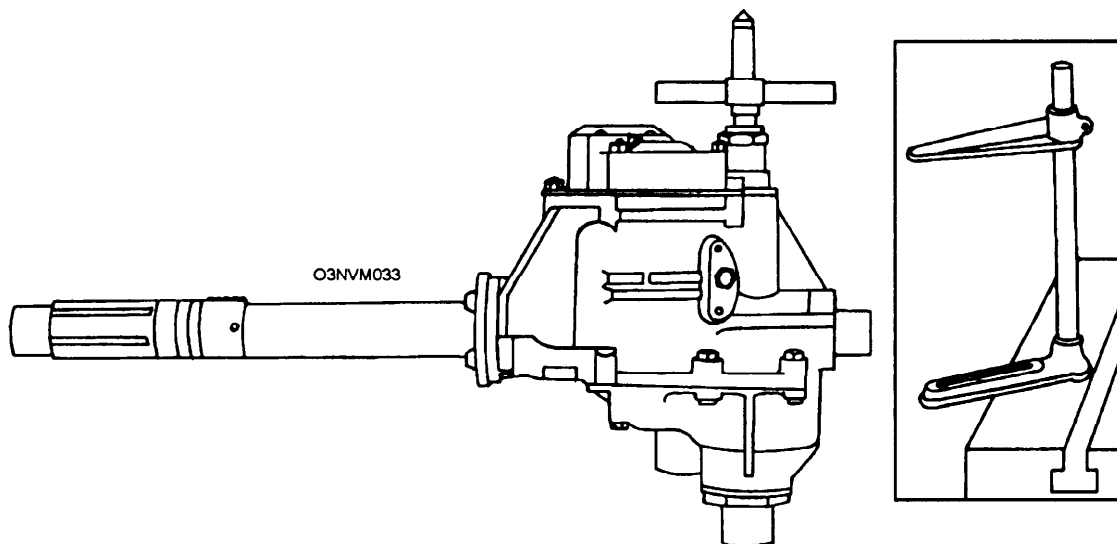

O3NVM033

Figure 5-33.—Heavy duty pneumatic drill and stand.

Another feature of this drill is a feed screw that can be used with a special type of drill stand called an "old man." This drill stand is shown in view B of figure 5-33. To drill a hole using the "old man," first place the twist drill in the socket. Adjust the feed screw in the machine to its lowest position and place the point of the feed screw in one of the indentations in the arm. Drill the hole to the required depth. Watch the drill; when it begins to come through. decrease the speed. Hold the drill motor up by hand so that it will not drop onto the work.

The pneumatic grinder, shown in figure 5-34, operates on the same basic principle as the pneumatic drill. It can be equipped with either a grinding wheel or a wire bristle wheel. After attaching the appropriate wheel, perform the preliminary steps required to connect the pneumatic grinder. Always run this machine so that the grinding surface of the wheel is square with the surface of the material being ground. Do not grind soft nonferrous metals, such as aluminum or brass, on a wheel that is designed for carbon and alloy steels. A silicon carbide abrasive wheel is suitable for grinding soft nonferrous metals, nonmetallic materials, and cemented carbides. Make sure that the rpm rating on the wheel is greater than that of the grinder. If the rpm rating of the grinder is greater than the wheel, the wheel stands a good chance of shattering and causing personnel injury from flying particles.

In recent years, we have started using several new types of pneumatic tools that are used for the setting of rivets and fasteners. As a result, rivets and fasteners can now be set easier and faster. The tools shown in figure 5-35 are relatively easy to operate, and you need to remember only the few simple precautions described in the following paragraphs.

Pneumatic tools must have thorough lubrication. The moving parts of a pneumatic tool are very closely
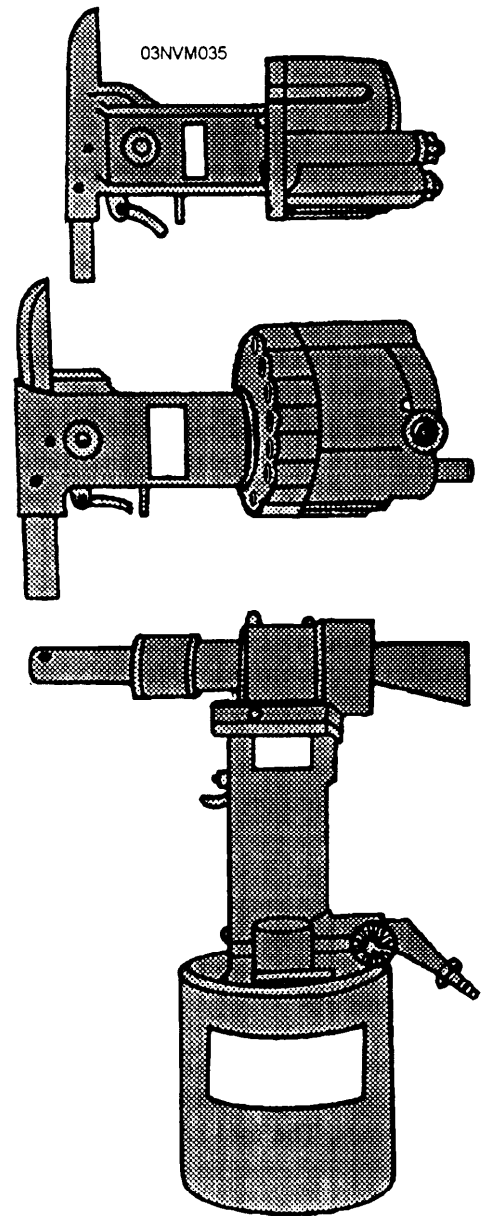

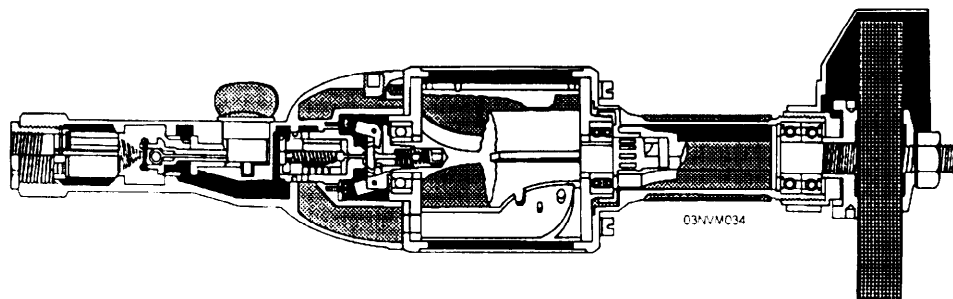**Figure 5-35.—Pneumatic rivet setting tools.**

Figure 5-34.—Sectional view of a pneumatic grinder.

fitted. If proper lubrication is neglected, they wear rapidly and fail within a short time.

Valves and pistons on pneumatic hammers require a light machine oil. Since the compressed air comes directly in contact with these parts, it has a tendency to drive the lubricant out through the exhaust. Therefore, when working steadily with any pneumatic tool, you should regularly check the lubricator. Make certain there is plenty of lubricant, and empty the filter assembly when needed. On low-pressure compressed air systems that do not have the filter, regulator, and lubricator assembly, you should disconnect the air hose every hour or so and squirt a few drops of light oil into the air hose connection. Heavy oil will cause precision parts to clog up and fail. If this happens, you will have to clean your tool in cleaning solvent to loosen the gummy substance. Then blow out the tool with air, lubricate it with a light oil, and go back to work.

Keep your pneumatic tools clean and lubricated, and you will have fewer operating troubles.

When using portable pneumatic power tools, there are certain safety precautions that you must observe.

- Always wear your goggles and hearing protection when working with these tools.

- Take care not to allow any of these tools to run out of hand. The pneumatic grinder especially will want to "walk" away from the point you want to grind.

- Always stand so that your feet won't slip while you are working. Make sure that you are properly balanced.

- Apply the grinding wheel to the work with gentle pressure. Sudden forcing may cause the wheel to shatter. As you complete the work, ease up on the pressure.

- Be careful not to allow the air hose to become kinked.

- Pneumatic grinders and sanders turn at a high rpm. Use only the approved type of grinding wheel or disk. The maximum operating rpm is shown on the side of the wheel or disk. Remember the rpm rate of the wheel must be higher than the rpm rate of the grinder or sander. Using a wheel with a lower rpm rate than the tool can cause the wheel to shatter.

THREAD-CUTTING TOOLS

Internal threads are cut with taps and tap wrenches. External threads are cut with dies and die stocks. All threads are not alike. They must be designed, selected, and cut to fit the job. As an HT, you will be concerned with two types of threads: machine threads and pipe threads.

Dies and taps for cutting machine threads are now made according to three basic sets of standards: American National, American Standard, and Unified Thread Standard (also referred to as "the standard"). Knowing just what these standards are is important.

The AMERICAN NATIONAL standards were widely used for many years. There are two series of American National machine threads with which you will be concerned. These are the American National Fine (NF) and the American National Coarse (NC) series. The form of the thread is the same for both National Fine and National Coarse; the difference is in the pitch or number of threads to the inch.

The second set of standards for threads is the AMERICAN STANDARD. The American Standard threads for machine screws are based on the older American National Standard. The two sets of standards are not identical, but some of the American Standard threads are identified by the old American National designation. For example, the American Standard Fine series is designated by NF and the American Standard Coarse series by NC.

The third set of standards is the UNIFIED THREAD STANDARD. This standard was agreed to by the United States, Canada, and the United Kingdom in 1948. It is expected that the Unified Thread Standard will become the generally accepted standard for machine threads, replacing the American Standard and the American National.

Many of the machine threads using these three basic standards are interchangeable; they are either identical or very similar in general form. The major differences between the Unified Thread Standard and the earlier standards are in the application of allowances, the variation of tolerance with size, the amount of pitch diameter tolerance, and the designation of the threads. In general, the Unified Thread Standard provides more classes of fit than did the earlier standards.

Pipe taps and dies differ from machine taps and dies in that most pipe threads are tapered to provide an airtight and liquid-tight seal. Pipe diameters are

measured as inside diameters; therefore, the wall thickness of the pipe must be taken into consideration. This means the pipe taps and dies are larger in diameter than the machine taps and dies. In other words, a 1/2-inch pipe tap or die is larger in diameter than a 1/2-inch machine tap or die.

The NPT, which formerly stood for National Pipe Thread, is still used as a carryover and now refers to the new name for the same thread, American Standard Taper Pipe Threads. The standard taper of pipe threads is three-fourths inch per foot. The number of threads per inch varies according to the size of pipe as follows:

- l/16- and 1/8-inch pipe have 27 threads per inch

- 1/4- and 3/8-inch pipe have 18 threads per inch

- 1/2- and 3/4-inch pipe have 14 threads per inch

- 1-, 1 1/4-, 1 1/2-, and 2-inch pipe have 11 1/2 threads per inch

- 2 1/2-inch pipe and pipe larger than 2 1/2 inches have 8 threads per inch

Hand pipe-threading tools are supplied by the Navy to cut external threads up to 4 inches and internal threads up to 4 inches. However, hand pipe-threading tools that will cut pipe up to 12 inches can be requisitioned through the supply department. Pipe over 3 inches in diameter is normally joined by oxyacetylene welding, arc welding, or by brazing with silver-base or copper-base alloys.

This section of the chapter contains instructions on how to select and use the taps and drills for the various standard thread sizes. You will also find a detailed explanation of how to use taper, plug, and bottoming taps, how to cut machine threads with taps and dies, and how to lubricate the work.

TAPS AND DIES

Taps and dies are used to cut threads in metal, plastics, or hard rubber. The taps are used for cutting internal threads, and the dies are used to cut external threads. There are many different types of taps. However, the most common are the taper, plug, bottoming, and pipe taps as shown in figure 5-36.
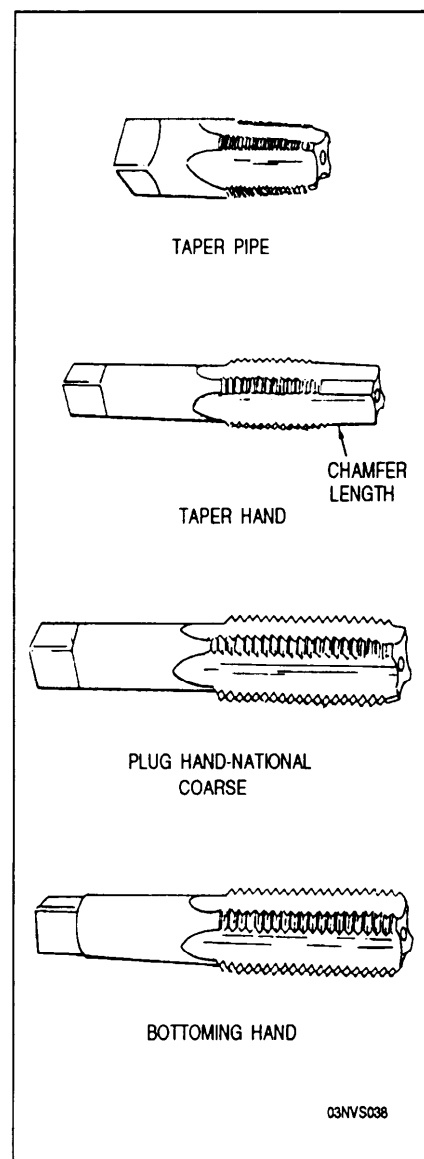

Figure 5-36.—Types of common taps.

The taper (starting) hand tap has a chamfer length of 8 to 10 threads. These taps are used when starting a tapping operation and when tapping through holes.

Plug hand taps have a chamfer length of 3 to 5 threads and are designed for use after the taper tap.

Bottoming hand taps are used for threading the bottom of a blind hole. They have a very short chamfer length of only 1 to 1 1/2 threads for this purpose. This tap is always used after the plug tap has already been used. Both the taper and plug taps should precede the use of the bottoming hand tap.

Pipe taps are used for pipe fittings and other places where extremely tight fits are necessary.

The tap diameter, from end to end of threaded portion, increases at the rate of 3/4 inch per foot. All the threads on this tap do the cutting, as compared to the straight taps where only the nonchamfered portion does the cutting.

Dies are made in several different shapes and are of the solid or adjustable type. The square pipe die (fig.

Figure 5-37.—Types of solid dies.

5-37) will cut American Pipe Thread only. It comes in a variety of sizes for cutting threads on pipe with diameters of 1/8 inch to 2 inches.

A rethreading die as shown (fig. 5-37) is used principally for dressing over bruised or rusty threads on screws or bolts. It is available in a variety of sizes for rethreading American Standard Coarse and Fine threads. These dies are usually hexagon in shape and can be turned with a socket, box, open-end, or any wrench that will fit. Rethreading dies are available in sets of 6, 10, 14, and 28 assorted sizes in a case.

Round split adjustable dies (fig. 5-38) are called "button" dies and can be used in either hand diestocks or machine holders. The adjustment in the screw-adjusting type is made by a fine-pitch screw that forces the sides of the die apart or allows them to spring together. The adjustment in the open adjusting types is made by three screws in the holder, one for expanding and two for compressing the dies. Round split adjustable dies are available in a variety of sizes to cut American Standard Coarse and Fine threads, special form threads, and the standard sizes of threads that are used in Britain and other European countries. For hand threading, these
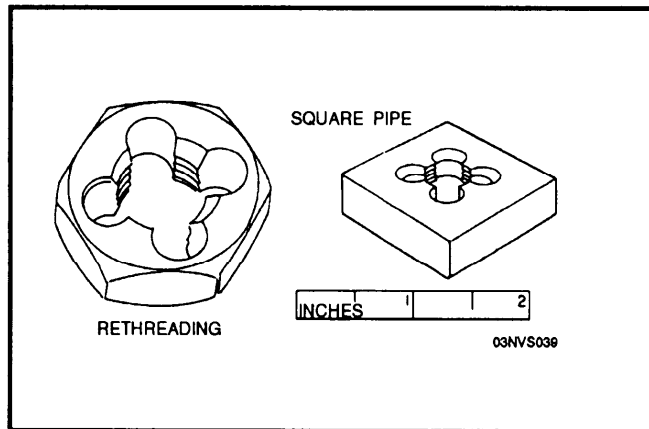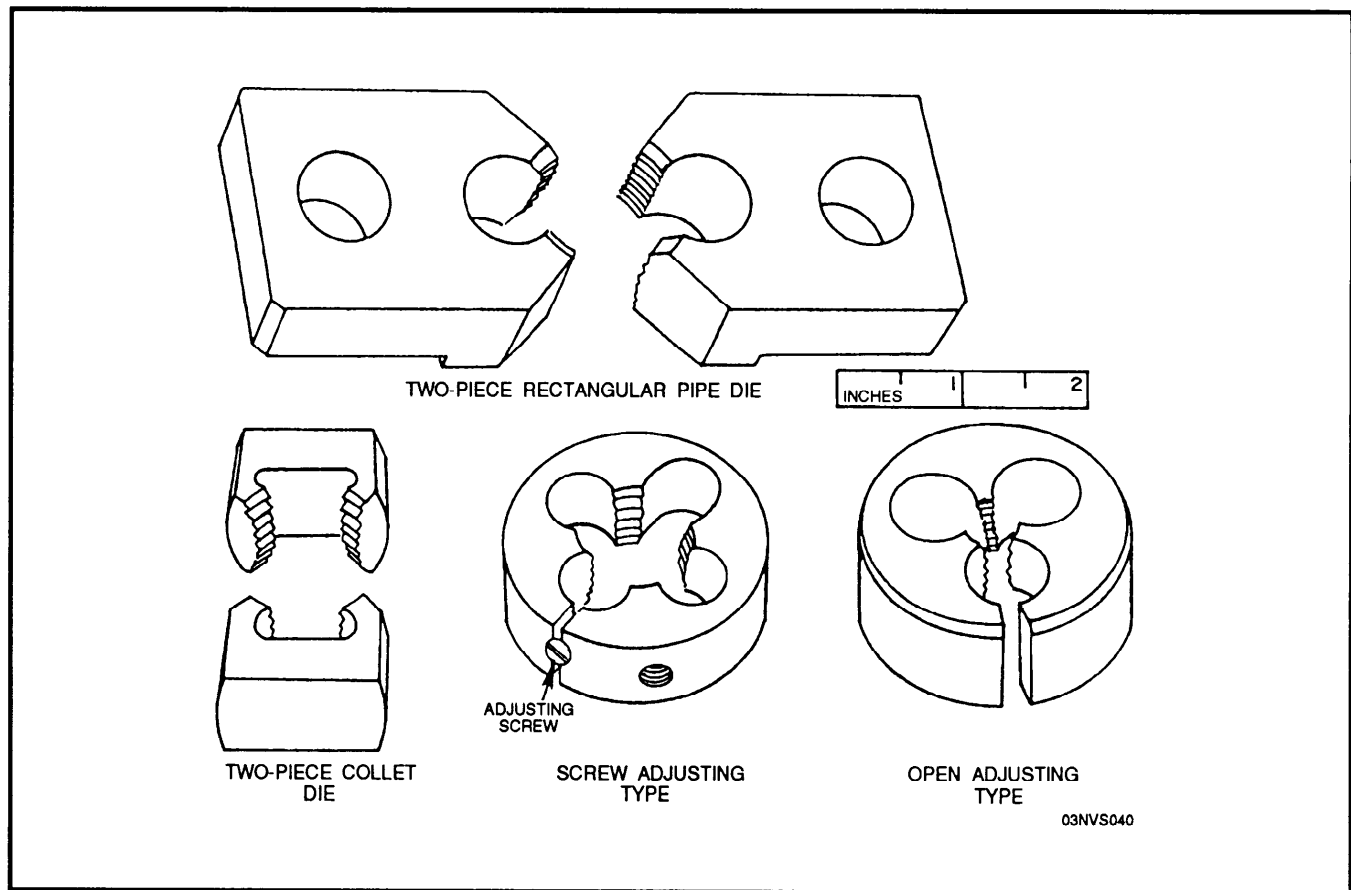

Figure 5-38.—Types of adjustable dies.

dies are held in diestocks, as shown in figure 5-39. One type of die stock has three pointed screws that will hold round dies of any construction, although it is made specifically for open adjusting-type dies.

Two-piece collet dies (fig. 5-38) are used with a collet cap (fig. 5-39) and collet guide. The die halves are placed in the cap slot and held in place by the guide that screws into the underside of the cap. The die is adjusted by setscrews at both ends of the internal slot. This type of adjustable die is issued in various sizes to cover the cutting range of American Standard Coarse, Fine, and special form threads. Diestocks to hold the dies come in three different sizes.

Two-piece rectangular pipe dies (fig. 5-38) are available to cut American Standard Pipe threads. They are held in ordinary or ratchet-type diestocks (fig. 5-40). The jaws of the dies are adjusted by setscrews. An adjustable guide keeps the pipe in alignment with respect to the dies. The smooth jaws of the guide are adjusted by a cam plate; a thumbscrew locks the jaws firmly in the desired position.

Threading sets are available in many different combinations of taps and dies, together with diestocks, tap wrenches, guides, and necessary screwdrivers and wrenches to loosen and tighten adjusting screws and
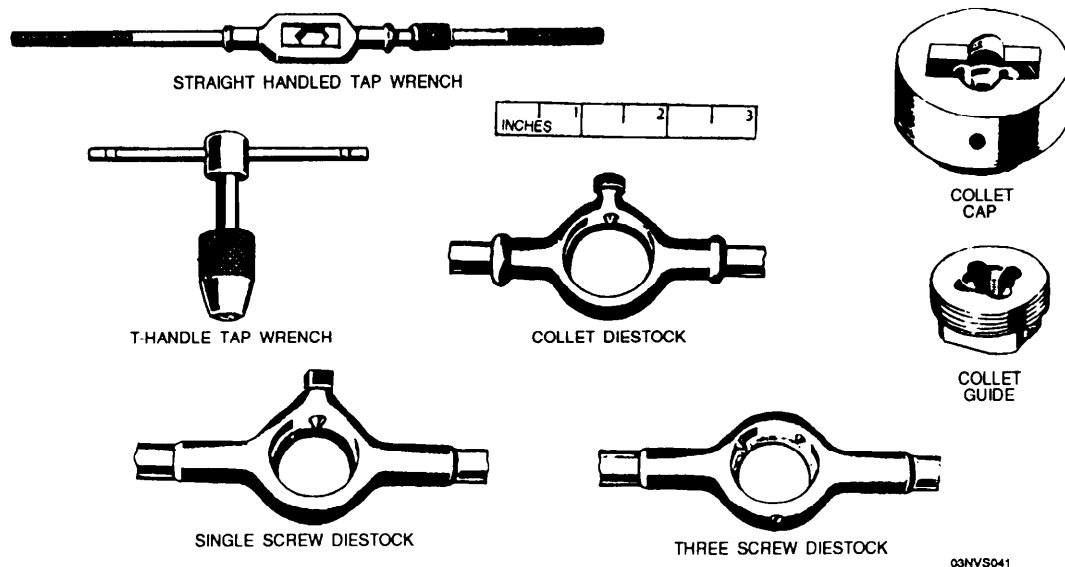
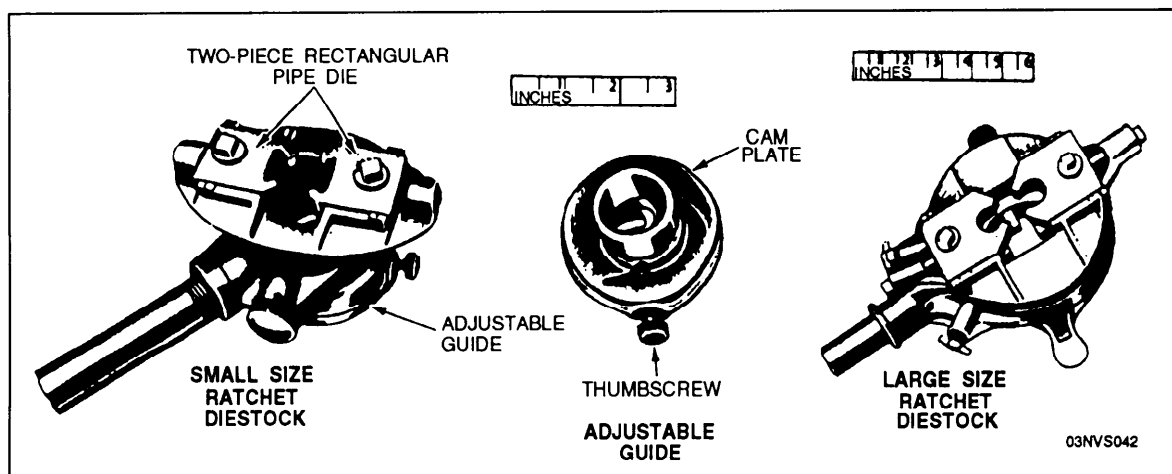Figure 5-39.—Diestocks, diecollet, and tap wrenches.

Figure 5-40.—Adjustable die guide and ratchet diestocks.

bolts. Figure 5-41 shows typical threading sets for pipe, bolts. and screws.

Never attempt to sharpen taps or dies. Sharpening of taps and dies involves several highly precise cutting processes, which involve the thread characteristics and chamfer. These sharpening procedures must be done by experienced personnel to maintain the accuracy and the cutting effectiveness of taps and dies.

Keep taps and dies clean and well oiled when not in use. Store them so that they do not contact each other or other tools. For long periods of storage, coat taps and dies with a rust preventive compound, place in individual or standard threading set boxes, and store in a dry place.
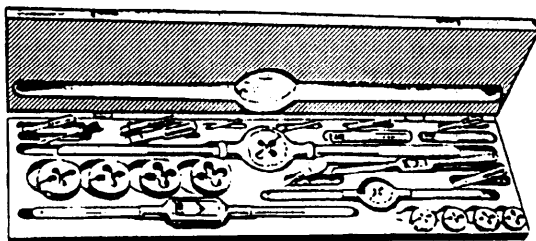
THREAD CHASERS

Thread chasers are threading tools that have several teeth and are used to rethread (chase) damaged external or internal threads, as shown in figure 5-42. These tools are available to chase standard threads. The internal thread chaser has its cutting teeth located on a side face. The external thread chaser has its cutting teeth on the end of the shaft. The handle end of the tool shaft tapers to a point.
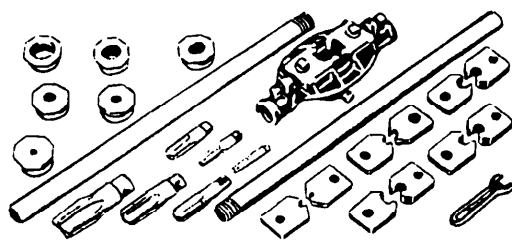
PIPE THREADING SET WITH RECTANGULAR
ADJUSTABLE DIES, DIESTOCK,
WRENCH, GUIDES AND TAPS

BOLT AND SCREW THREADING SET WITH
ROUND ADJUSTABLE SPLIT DIES,
DIESTOCKS, TAPS, TAP WRENCHES,
AND SCREWDRIVERS   03NVS043

Figure 5-41.—Threading sets.

EXTERNAL - 12 TPI   03NVM042

INTERNAL - 12 TPI

EXTERNAL - 32 TPI

INTERNAL - 32 TPI
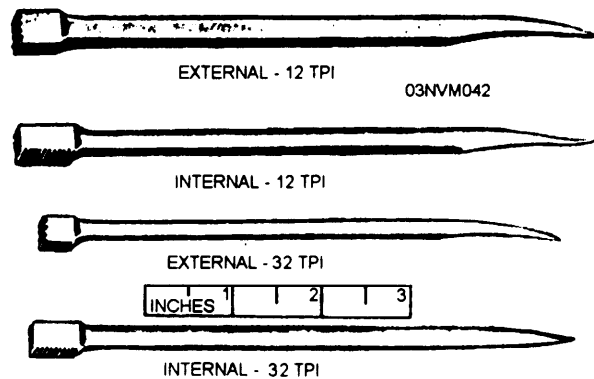
Figure 5-42.—Thread chasers.

THREADS AND THREAD CUTTING

Threads are helical ridges cut into screws, nuts, bolts, or the walls of a hole, so that the action of turning the screw, nut, or bolt gives it endwise as well as rotary motion. Many thread types exist. These types include bolt threads, machine screw threads, and pipe threads. Before we proceed with descriptions of thread-cutting procedures, we must become familiar with the terminology to be used.

Thread Terminology

Refer to figure 5-43 and note that the outside diameter of a thread is known as the MAJOR

Figure 5-43.—Thread terminology.

Figure 5-44.—Tap drill size determination.

DIAMETER. The diameter across the roots of the thread is called the MINOR DIAMETER. The PITCH is defined as the distance from any point on the thread of a screw to the corresponding point on an adjacent thread. It is usually measured from crest to crest and is expressed by a specific quantity of threads per inch.
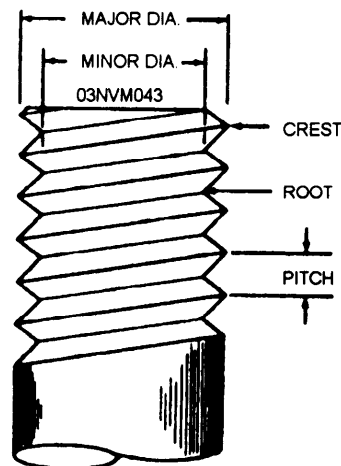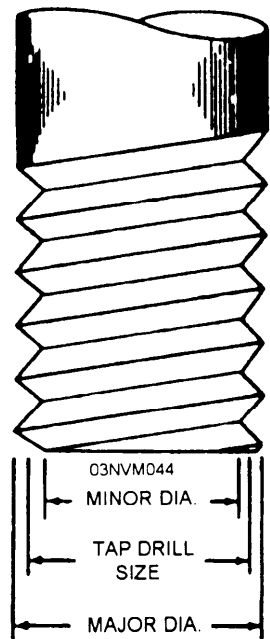
Tap Drill Determination

If a threaded hole is to be made in a piece of metal, a hole of suitable size must first be drilled. The hole must be somewhat smaller than the size of the bolt to be screwed into it.

How do you determine how much smaller to drill this hole? Figure 5-44 shows the system used for figuring this. The resultant thread is known as a "75 percent thread" because the diameter of the hole is 75

Figure 5-46.—Oversize drilled hole for tapping.

percent of the difference between the major and minor diameters, subtracted from the major diameter.

When the tap hole is the right size, it is a little larger than the root diameter of the tap, as shown in figure 5-45. The tap will cut a thread in the work which is only 75 percent as deep as the thread on the tap. The other 25 percent of the depth of thread on the tap provides clearance between the tap hole and the root diameter of the tap (see fig. 5-45). This makes tapping easier.

If the tap drill selected is oversize, the tap hole will be oversize, and the tap can cut only shallow threads in the work, as shown in figure 5-46. With less than a full 75 percent depth of thread, stud or capscrew threads usually strip.

If the tap drill selected is undersize, the tap hole will be undersize, being perhaps equal to the root diameter of the tap, as shown in figure 5-47. Then there will be no clearance, and the tap will turn hard, tear the threads, and probably break.

The best method to determine the exact size of tap drill to use is to refer to table 5-2. A chart similar to this generally is included with a set of taps and dies.

Figure 5-45.—Proper size drilled hole for tapping.

Figure 5-47.—Undersize drilled hole for tapping.

Table 5-2.—American National Form Threads

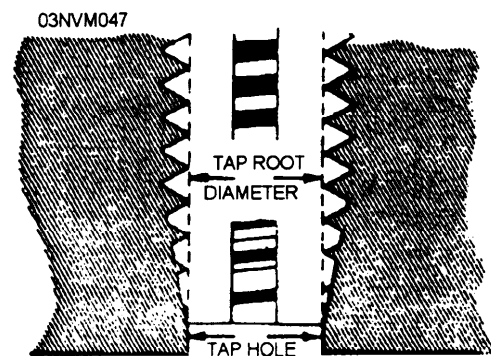| Nominal size	Thread Series	Major Diameter, inches	Root diameter, inches	Tap drill to produce approx. 75 % full thread	Decimal equivalent of tap drill
0–80	N. F.	.0600	.0438	3/64	.0469
1–64	N. C.	.0730	.0527	53	.0595
72	N. F.	.0730	.0550	53	.0595
2–56	N. C.	.0860	.0628	50	.0700
64	N. F.	.0860	.0657	50	.0700
3–18	N. C.	.0990	.0719	47	.0785
56	N. F.	.0990	.0758	45	.0820
4–10	N. C.	.1120	.0795	43	.0890
48	N. F.	.1120	.0849	42	.0935
5–40	N. C.	.1250	.0925	38	.1015
44	N. F.	.1250	.0955	37	1040
6–32	N. C.	.1380	.0974	36	.1065
40	N. F.	.1380	.1055	33	.1130
8–32	N. C.	.1640	.1234	29	.1360
36	N. F.	.1640	.1279	29	.1360
10–24	N. C.	.1900	.1359	25	.1495
32	N. F.	.1900	.1494	21	.1590
12–24	N. C.	.2160	.1619	16	.1770
28	N. F.	.2160	.1696	14	.1820
1/4–20	N. C.	.2500	.1850	7	.2010
28	N. F.	.2500	.2036	3	.2130
5/16–18	N. C.	.3125	.2403	F	.2570
24	N. F.	.3125	.2584	I	.2720
3/8–16	N. C.	.3750	.2938	5/16	.3125
24	N. F.	.3750	.3209	Q	.3320
7/16–14	N. C.	.4375	.3447	U	.3680
20	N. F.	.4375	.3726	25/64	.3906
1/2–13	N. C.	.5000	.4001	27/64	.4219
20	N. F.	.5000	.4351	29/64	.4531
9/16–12	N. C.	.5625	.4542	31/64	.4844
18	N. F.	.5625	.4903	33/64	.5156
5/8–11	N. C.	.6250	.5069	17/32	.5312
18	N. F.	.6250	.5528	27/64	.5781
3/4–10	N. C.	.7500	.6201	21/32	.6562
16	N. F.	.7500	.6688	11/16	.6875
7/8–9	N. C.	.8750	.7307	49/64	.7656
14	N. F.	.8750	.7822	13/16	.8125
1–8	N. C.	1.0000	.8376	7/8	.8750
14	N. F.	1.0000	.9072	15/16	.9375
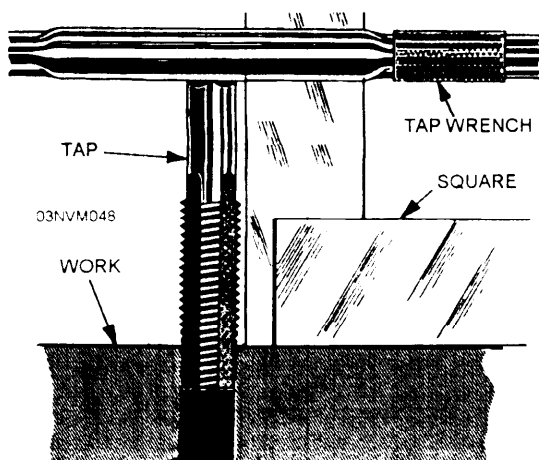
Figure 5-48.—Using a square to ascertain a tap is square with the work.

Cutting Machine Threads With Taps

Mineral lard oil, applied with a small brush, is highly recommended as a lubricant when tapping in steel. When using this lubricant, tighten the tap in the tap wrench and apply the lubricant to the tap. Start the tap carefully with its axis on the center line of the hole. The tap must be square with the surface of the work, as shown in figure 5-48.

To continue tapping, turn the tap forward two quarter turns, back it up a quarter turn to break the chips, and then turn forward again to take up the slack. Continue this sequence until the required threads are cut. After you cut for the first 2 or 3 full turns, you no longer have to exert downward pressure on the wrench. You can tell by the feel that the tap is cutting as you turn it. Don't permit chips to clog the flutes or they will prevent the tap from turning. When the tap won't turn and you notice a springy feeling, stop trying
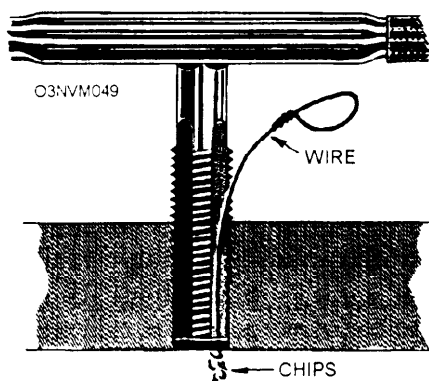

Figure 5-49.—Using a wire to clear chips from the flute of a tap.
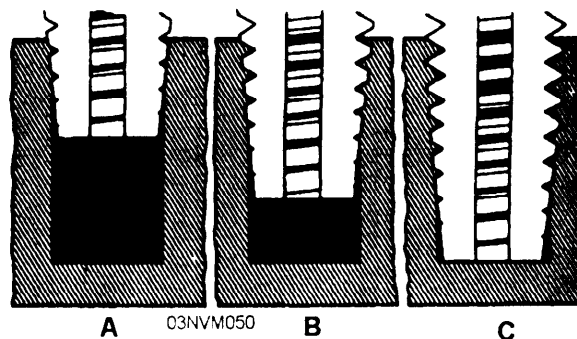
Figure 5-50.—Tapping a blind hole with a taper tap.

immediately. Back the tap up a quarter turn to break the chips, clean them out of the flutes with a wire (as shown in fig. 5-49), add some more lubricant, and continue tapping. When the tap has cut threads through the hole, the tap will turn with no resistance.

To tap a blind hole, start with the taper tap. For a blind hole you will need all three types—the taper, plug, and bottoming taps. Be sure they are the size and thread series you need, and that the tap hole is the size called for by the working drawing and table 5-2.

Begin with the taper tap. Handle it as described earlier. Figure 5-50, view A, shows the taper tap just starting to cut. In figure 5-50, view B, it has cut a little farther. In figure 5-50, view C, it has bottomed in the hole after having cut several full threads near the top of the hole. This completes the work to be done with the taper tap.

In figure 5-51, view A, the plug tap has entered the few full threads cut by the taper tap. In figure 5-51, view B, it has continued these threads a little farther down into the hole. In figure 5-51, view C, it has bottomed in the hole. This is all the work that you can do with the plug tap. It has cut full threads about halfway down the tap hole before bottoming.

Figure 5-51.—Tapping a blind hole with a plug tap.

In figure 5-52, the bottoming tap has been substituted for the plug tap. In figure 5-52, view A, it has been run down the full th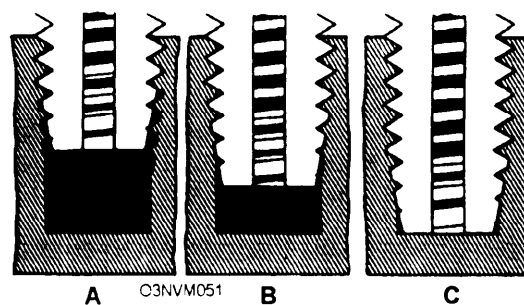reads cut by the plug tap and is ready to cut more full threads. In figure 5-52, view B, it has cut a few more threads, and in figure 5-52, view C, it has bottomed in the hole. The blind hole has now been completely tapped.

Because these threads are being tapped in a blind hole, you must remove chips differently. To remove chips, back the tap completely out of the hole very frequently, invert the stock, if possible, and jar out the chips or work them out of the hole with a wire while the stock is in the inverted position.

Chip removal in tapping blind holes is much more difficult to do and is very important because chips will fall ahead of the tap through the flutes and accumulate in the bottom of the blind hole. Until these chips are removed, none of the three taps can complete its work. In tapping blind holes, alternate with tapping and chip removal until each of the three taps bottom in the blind hole.

When you have finished using the three taps, brush the chips out of their teeth, oil them well with lubricating oil, wipe off the surplus oil, and replace them in the threading set.

INSTALLED MACHINE TOOLS

The Navy furnishes modern equipment to help you perform your duties. This section introduces you to some of the most common machine tools found in workshops that you should be familiar with. A machine tool is a power-driven machine that holds the material and cutting tool and brings them together so the material is drilled, cut, shaved, or ground.

The machine tools described in this chapter are found in most well-equipped shops. Other machine tools for specific types of work will be described in their appropriate chapter of this training manual.
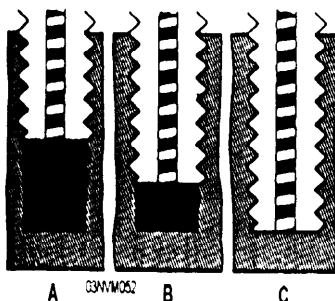
Figure 5-52.—Finish tapping a blind hole with a bottoming tap.

SAFETY PRECAUTIONS

Before using any machine tool, you must be familiar with all safety precautions pertaining to its operation. Carelessness around any moving machinery is extremely dangerous. When moving machinery is equipped with sharp cutting tools, the dangers are greatly increased. The following list includes some of the more general safety precautions for machine tools. Specific safety precautions should be posted in plain sight by every machine.

- Do not lean against any machine that is in motion. Keep clear of all gears, belts, and other moving parts. Never remove the guards from any part of an operating machine.

- Never start a machine unless you are thoroughly familiar with its operation.

- Do not attempt to clean, adjust, or repair a machine while it is in motion. NEVER attempt to clean running gears.

- PROTECT YOUR EYES. Do not hold your head too close to the cutting tool. Flying bits of metal or scale may get into your eyes. Always wear goggles when there is any danger of flying particles getting in your eyes— for example, when using a grinding or drilling machine.

- PROTECT YOUR HEARING. Always wear appropriate hearing protection. Either audio headsets or ear plugs will filter the noise from running machinery. Prolonged exposure may damage your hearing.

- Keep your fingers away from the cutting edges when the machine is in operation. Otherwise, you could lose some fingers.

- Do not wear gloves or loosely hanging clothes. They can be caught by moving parts of the shop machinery and cause serious injuries. Keep your sleeves rolled up tightly above the elbows. Do not wear neckties or loose neckerchiefs.

- In all machine work, stress SAFETY first, ACCURACY second, and SPEED last. Excessive speed is both dangerous and inefficient.

METAL-CUTTING SAWS

Metal-cutting saws are standard equipment in repair facilities. They are used for nonprecision cutting of
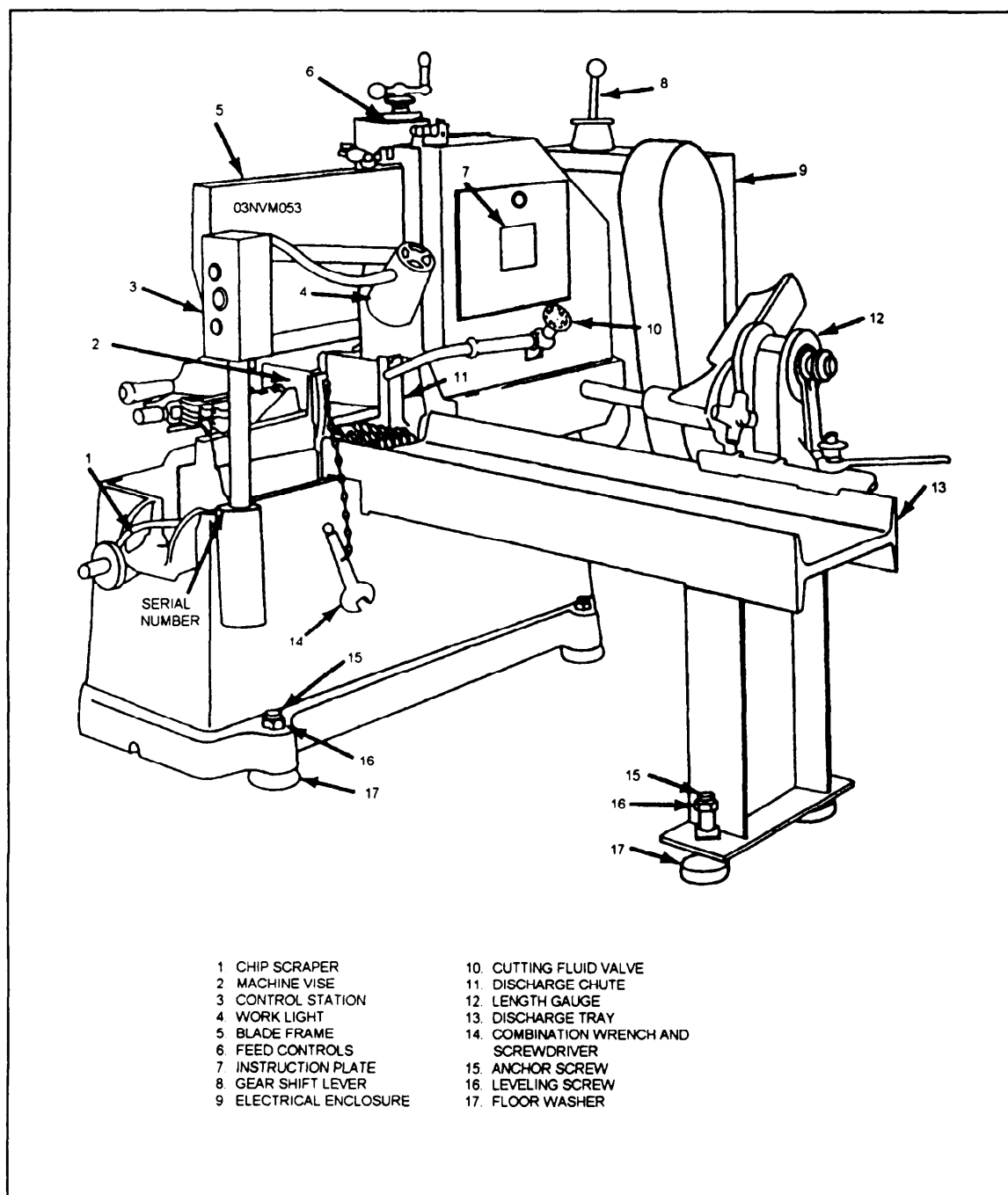
Figure 5-53.—Power hacksaw.

1.	CHIP SCRAPER	10.	CUTTING FLUID VALVE
2.	MACHINE VISE	11.	DISCHARGE CHUTE
3.	CONTROL STATION	12.	LENGTH GAUGE
4.	WORK LIGHT	13.	DISCHARGE TRAY
5.	BLADE FRAME	14.	COMBINATION WRENCH AND
6.	FEED CONTROLS		SCREWDRIVER
7.	INSTRUCTION PLATE	15.	ANCHOR SCREW
8.	GEAR SHIFT LEVER	16.	LEVELING SCREW
9.	ELECTRICAL ENCLOSURE	17.	FLOOR WASHER

various metals and can cut any reasonable size or shape. In the pipe shop, bandsaws are used to cut pipe and tubing for various types and sizes at different angles. In the shipfitter shop, metal-cutting saws are used to cut angle iron, pipe, zincs, bar stock, and numerous other stock. In the carpenter shop, saws are used to cut wooden patterns, miter frames, stock, and for other similar applications. Metal-cutting saws can cut brass, bronze, aluminum, Monel, and thin sections of carbon steel casting and other types of metals.

Since the metal-cutting saw cuts materials of varying thickness, toughness, and hardness, you must select the proper blade for each job. Blade design and

uses are presented later in this chapter to help you understand the differences in blades.

POWER HACKSAWS

The power hacksaw (fig. 5-53) is found in all except the smallest shops. It is used to cut bar stock, pipe, tubing, or other metal stock. It consists of a base, a mechanism for causing the saw frame to reciprocate, and a clamping vise for holding the stock while it is being sawed. There are two types of power hacksaws: the direct mechanical drive and the hydraulic drive.

The power hacksaw shown in figure 5-53 has a capacity of 4" × 4". This means it can handle material up to 4 inches wide and 4 inches high.

A power hacksaw will have one of three typos of feed mechanisms:

● Mechanical feed, which ranges from 0.001 to 0.025 inch per stroke, depending upon the class and type of material being cut

● Hydraulic feed, which normally exerts a constant pressure, but is designed so that the feed stops automatically at hard spots to decrease the pressure on the saw until the hard spot has been cut through.

● Gravity feed, in which weights are placed on the saw frame and shifted to give more or less pressure of the saw blade against the material being cut.

All three types of feed mechanisms lift the blade clear of the work during the return stroke.

Hacksaw Blades

The blade shown in figure 5-54 is especially designed for use with the power hacksaw. It is made with a tough alloy steel back and high-speed steel teeth. This combination gives both a strong blade and a cutting edge suitable for high-speed sawing.

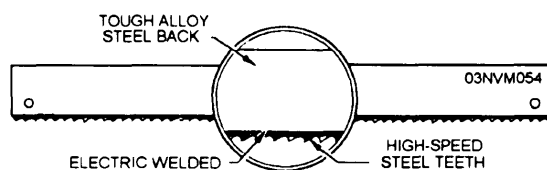These blades vary as to the pitch of the teeth (number of teeth per inch). The correct pitch for a particular job is determined by the size and material composition of the section and the material to be cut. Use coarse pitch teeth for wide, heavy sections to provide ample chip clearance. For thinner sections, use a blade with a pitch that will keep two or more teeth in contact with the work so that the teeth will not straddle the work and strip the teeth. In general, you should select blades according to the following information:

● Coarse (4 teeth per inch) for soft steel, cast iron, and bronze

● Regular (6 to 8 teeth per inch) for annealed high-carbon steel and high-speed steel

● Medium (10 teeth per inch) for solid brass stock, iron pipe, and heavy tubing

● Fine (14 teeth per inch) for thin tubing and sheet metals

speeds

Speed for hacksaws is stated in strokes-per-minute, counting only those strokes that cause the blade to make a cut on the stock are counted. A gear shift lever is used to change speeds. There may be a card attached to or near the saw giving recommended speeds for cutting various metals. However, you may use the following speeds:

— Cold-rolled or machine steel, brass, and soft metals—136 strokes per minute.

— Alloy steel, annealed tool steel, and cast iron—90 strokes per minute.

— High-speed steel, unannealed tool steel, and stainless steel—60 strokes per minute.

Coolants

You should use a coolant for most power hacksawing operations. (Cast iron should be dry when it is cut.) The coolant prevents overheating of the blade and stock along with increasing the cutting rate. A soluble oil solution with a mixture of the oil and water will be suitable for most sawing operations. The normal mixture for soluble oil is 40 parts water to 1 part oil. You also may use a synthetic coolant.

METAL-CUTTING BANDSAW MACHINES

Metal-cutting bandsaw machines are standard equipment on all repair ships and tenders. These

Figure 5-54.—Power hacksaw blade.

machines can be used for nonprecision cutting similar to that performed by power hacksaws. Some types can also be used for precision cutting, filing, and polishing. A bandsaw machine is more flexible for straight cutting than a power hacksaw in that it can cut objects of any reasonable size and of regular and irregular shapes. A power hacksaw has a more limited capacity; it can only cut pieces with regular shapes. Also, the bandsaw cuts much faster than the hacksaw because the cutting action of the blade is continuous.

Figure 5-55 shows a tiltable blade bandsaw. The blade may be set either upright or at any angle up to 45 degrees from the vertical. The work is held stationary in a vise and the blade is moved into the work.

Figure 5-56 shows a tiltable table bandsaw. On the type shown, you should feed work either manually or by power to the blade, which runs in a fixed position. During recent years, the tiltable table bandsaw has been installed in most repair shops on repair ships and tenders.

A third type of bandsaw is designed for heavier work and has neither a tiltable blade nor a tiltable table. You will find this type on some ships.

Many of the new models, such as the one shown in figure 5-56, also have a job selector mounted on the machine. The names of various materials are inscribed on the outer ring of the selector. This ring is movable and can be positioned so that the name of any specific material can be brought into alignment with the window slot at the bottom of the dial. The numbers or letters that
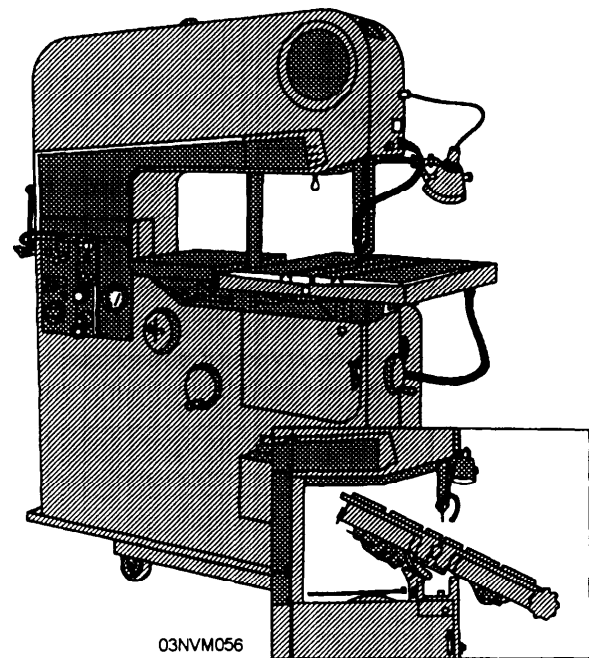
Figure 5-56.—Tiltable table-type (contour) metal-cutting bandsaw.

appear in the window, read in conjuction with stationary entries on the dial face, give the correct saw pitch, set and temper, saw velocity, and power feed pressure needed to cut that particular material.

Another type of metal-cutting bandsaw is shown in figure 5-57. This horizontal band cutoff saw is being used in shops on some ships to replace the reciprocating-type power hacksaw. The continuous cutting action of the blade provides greater speed, accuracy, and versatility.
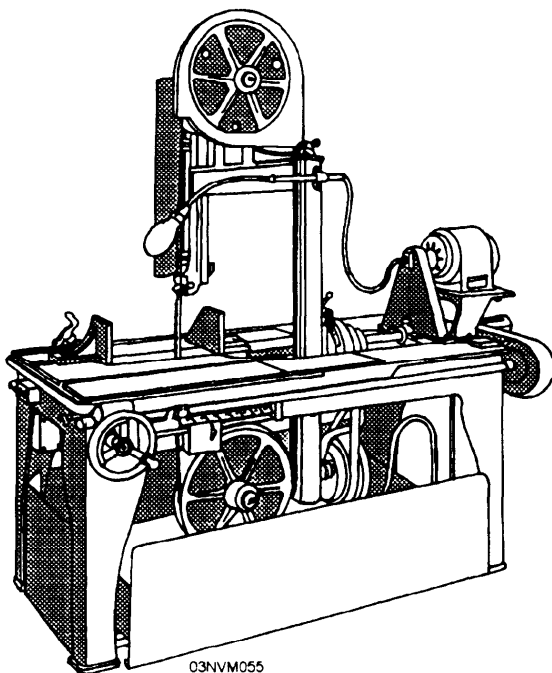
Figure 5-55.—Tiltable blade metal-cutting bandsaw.
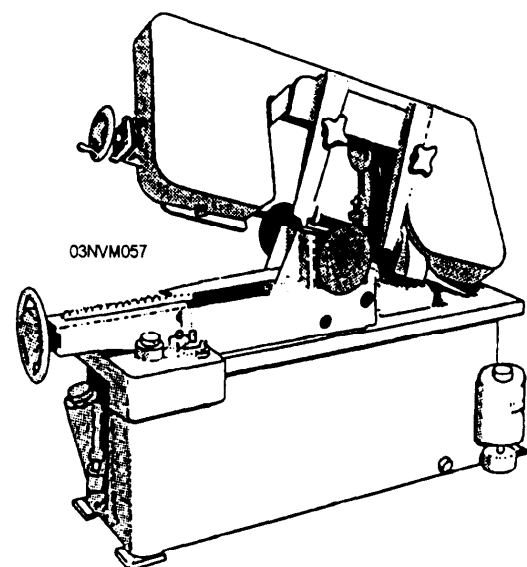
Figure 5-57.—Horizontal band cutoff saw.

5-32

Good results from the use of any metal-cutting bandsaw depends upon the careful choice of a blade. Tooth pitch should be considered in relation to the hardness and toughness of the material being worked, and the thickness of the workpiece. At least two teeth should be in contact with the work at all times during the cutting operation. When you cut thick material, select a tooth pitch that allows the smallest possible number of teeth to be in contact with the material. More teeth in contact means that a greater feed pressure is required to force them into the material. Excessive feed pressure will cause the cut to be off the mark.

Saw Bands

A saw band has the following characteristics, which are illustrated in figure 5-58.

PITCH: The number of teeth per linear inch. Every saw blade has a specific even number of teeth per linear inch. Normally this is from 6 to 32 teeth per inch of blade.

WIDTH: The distance across the flat surface of the saw band (back to the tip of the tooth). The width measurement is always expressed in inches or fractions of an inch. Blades are available in widths up to 1 inch.
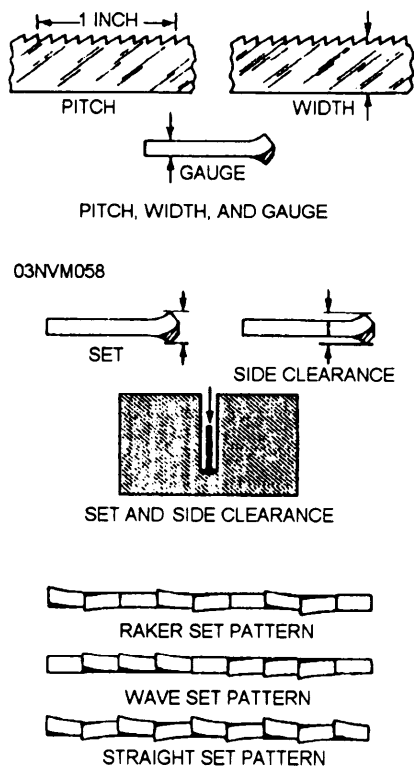

Figure 5-58.—Saw band characteristics.

GAUGE: The thickness of a blade. This measurement is expressed in thousandths of an inch. Saw bands come in three gauges—0.025, 0.032, and 0.035 inch.

SET: The bend or spread given to the teeth to provide clearance for the body of the blade when you make a cut.

SIDE CLEARANCE: The difference between the dimension of the gauge of the blade and the set of the teeth. Side clearance provides running room for the body of the blade in the kerf or cut. Without side clearance, the saw band will bind in the kerf.

SET PATTERN: One of three distinct patterns (raker, wave, and straight) in which teeth are set. The raker set pattern is used to cut solid cross-section work. The wave set pattern is used to cut hollow materials, such as pipes and tubing. The straight set pattern is not used to any great extent to cut metal.

TEMPER: The degree of hardness of the teeth, indicated by the letters *A* and *B*, with temper A being the harder. The A or B designation will only be found on the container the blade was shipped in. Temper A saw blades are used for practically all bandsaw metal-cutting work.

GRINDERS

Grinders are simple machines that allow you to reshape, form, and sharpen metal-cutting tools, or other tools. The type of grinder discussed in this chapter is the pedestal grinder.

The main parts of a pedestal grinder are as follows:

● A motor with an extended shaft for mounting grinding wheels.

● A mounting base for the motor.

● An adjustable tool rest for steadying the work piece for grinding.

● Wheel guards mounted over the grinding wheel as a safety feature.

● A shield fastened to the wheel guards to protect the operator from flying chips

The pedestal grinder is one of the most common and versatile machine found in most shops. You will probably use this piece of equipment more than any other piece of equipment found in your shop. You will use it to clean welds, remove burrs, sharpen tools, dress up

torch cuts, buff sheet metal, and for numerous other functions. Not only must you be able to use a pedestal grinder, but you also must observe all important operating and safety precautions.

Grinding Safety

The grinding wheel is a fragile cutting tool that operates at high speeds. Therefore, the safe operation of pedestal grinders is as important as proper grinding techniques. Observance of posted safety precautions is mandatory for the safety of the operator and the safety of personnel in the nearby vicinity.

What are the most common sources of injury during grinding operations? Hazards leading to eye injury caused by grit generated by the grinding process are the most common and the most serious. Abrasions caused by bodily contact with the wheel are quite painful and can be serious. Cuts and bruises caused by segments of an exploded wheel, or a tool "kicked" away from the wheel are other sources of injury. Cuts and abrasions can become infected if not protected from grit and dust from grinding.

Safety in using pedestal grinders is primarily a matter of using common sense concentrating on the job at hand. Each time you start to grind a tool, stop briefly to consider how observance of safety precautions and the use of safeguards protect you from injury. Consider the complications that could be caused by your loss of sight, or loss or mutilation of an arm or hand.

The following operating instructions and safety precautions are applicable in general to all grinders and specifically to the pedestal grinders.

— Read posted safety precautions before you start to use a machine. In addition to refreshing your memory about safe grinding practices, this gets your mind on the job at hand.

— Secure all loose clothing and remove rings or other jewelry.

— Inspect the grinding wheel, wheel guards, the tool rest, and other safety devices to ensure they are in good condition and positioned properly. Set the tool rest so that it is within 1/8 inch of the wheel face and level with the center of the wheel.

— Use light pressure when you start grinding; too much pressure on a cold wheel may cause failure.

— Grind only on the face or outer circumference of a grinding wheel unless the wheel is specifically designed for side grinding.

— Use a coolant to prevent overheating the work.

— Wear goggles and respiratory filters to protect your eyes and lungs from injury by grit and dust generated by grinding operations.

— Transparent shields, if installed, should be clean and properly adjusted. Transparent shields do not preclude the use of goggles as the dust and grit may get around a shield. Goggles, however, provide full eye protection.

— When starting a grinder, push the start button and stand to one side for at least 1 minute while the machine comes up to full speed. There is always a possibility that a wheel may shatter when coming up to speed.

— Never force work against a cold wheel. Apply work gradually to give the wheel an opportunity to warm. This will minimize the possibility of breakage.

— Handle wheels carefully. Before replacing a wheel on a grinder, always sound the new wheel for cracks. To sound a wheel, tap it lightly with a piece of hard wood. A good wheel gives out a clear ringing sound, and a cracked wheel gives out a dull "thud." Make sure that a fiber or rubber gasket is in place between each side of the wheel and its retaining washer (spindle wheel flange). Tighten the spindle nut just enough to hold the wheel firmly. If the nut is tightened too much, the clamping strain may damage the wheel.

— When selecting a replacement wheel, check to be sure that the grinder rpm will not exceed the manufacturer's recommended speed for the wheel.

— When grinding, always keep the work moving across the face of the wheel. This will prevent grooves from being worn into the face of the wheel.

— Keep all wheel guards tight and in place.

— Keep the spindle bearings well oiled.

— Dress wheels frequently to keep them clean, sharp, and true, but do not remove any more material than necessary.

— Keep the tool rest adjusted so that it just clears the wheel (never more than one-sixteenth inch) and is at or just below the center line of the wheel. This will prevent accidental jamming of the work between the toolrest and the wheel.

— Do not wear gloves when operating a pedestal grinder.

— If a lot of metal is to be removed, use the coarse wheel to remove most of it.

— Use a gauge, template, or a sample for comparison, unless you are familiar with the exact finished shape of the article you are grinding.

Grinding Wheels

A grinding wheel is made up of two basic elements: (1) the abrasive grains and (2) the bending agent. The abrasive grains may be compared to many single-point tools embedded in a toolholder of bonding agent. Each of these grains removes a very small chip from the material as it makes contact on each revolution of the grinding wheel.

An ideal cutting tool is one that will sharpen itself when it becomes dull. This, in effect, is what happens to the abrasive grains. As the individual grains become dull, the pressure that is generated on them causes them to fracture and present new sharp cutting edges to the work. When the grains can fracture no more, the pressure becomes too great and they are released from the bond, allowing a new layer of sharp grains to be presented to the work.

SIZES AND SHAPES.—Grinding wheels come in various sizes and shapes. The size of a grinding wheel is given in terms of its diameter in inches, the diameter of its spindle hole, and the width of its face. Grinding wheels have too many shapes to list in this manual, however, figure 5-59 shows those used most often. The type numbers are standard and are used by
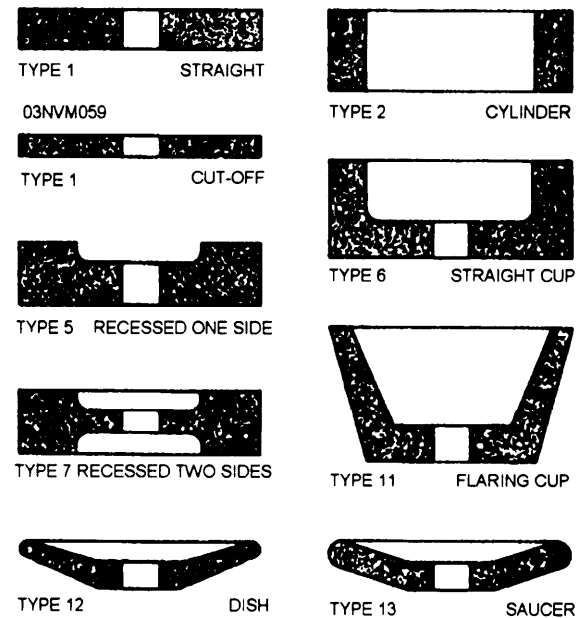
Figure 5-59.—Grinding wheel shapes.

all manufacturers. The shapes are shown in cross-sectional views. The specific job will dictate the shape of wheel you should use.

WHEEL MARKINGS AND COMPOSITION.—Grinding wheel markings are comprised of six sections, each of which identifies a characteristic of the wheel. The six sections are (1) type of abrasive, (2) grain size, (3) bond grade, (4) structure, (5) type of bond, (6) the manufacturer's record symbol. Figure 5-60 shows the standard marking system and possible

Figure 5-60.—Standard marking system for grinding wheels (except diamond).

5-35

variations that identify nearly all abrasives except diamond. The following information breaks the marking down and explains each section. Follow the sections in the figure from left to right as you read an explanation of each section in the following paragraphs. This information should be studied carefully as it will be invaluable in making the proper wheel selection for each grinding job you will attempt.

Type of Abrasive.—The first section on the grinding wheel marking shows the type of abrasive. There are two types of abrasives: natural and manufactured. Natural abrasive, such as emery, corundum, and diamond, are used only in honing stones and in special types of grinding wheels. The common manufactured abrasives are aluminum oxide and silicon carbide. They have superior qualities and are more economical than natural abrasives. Aluminum oxide (designated by the letter *A)* is used to grind steel and steel alloys, and for heavy duty work such as cleaning up steel castings. Silicon carbide (designated by the letter C), is harder but not as tough as aluminum oxide. It is used mostly for grinding nonferrous metals and carbide tools. The abrasive in a grinding wheel makes up about 40 percent of the wheel.
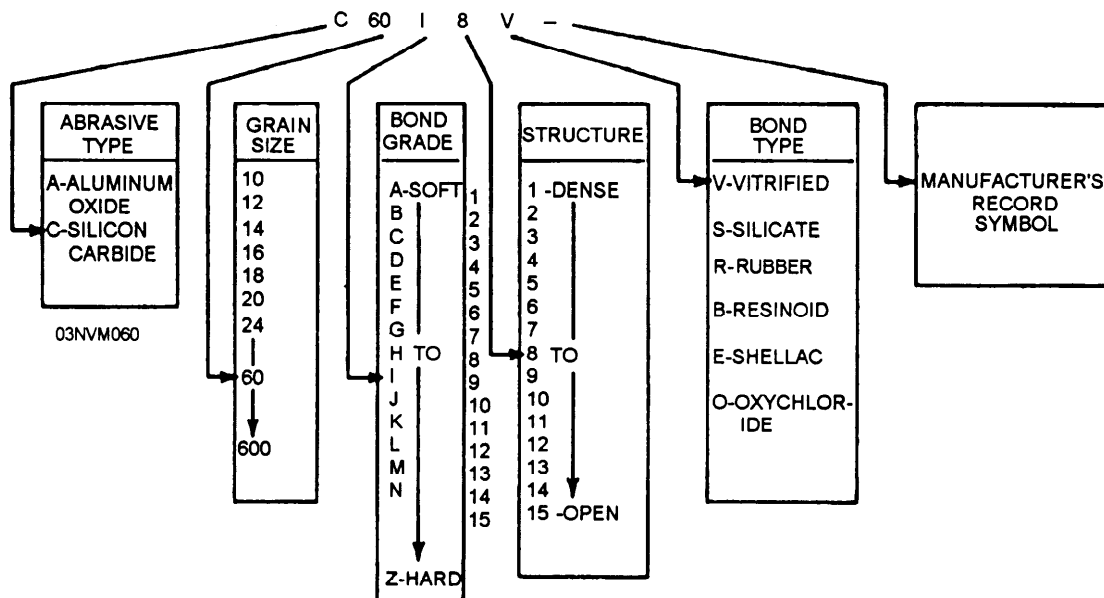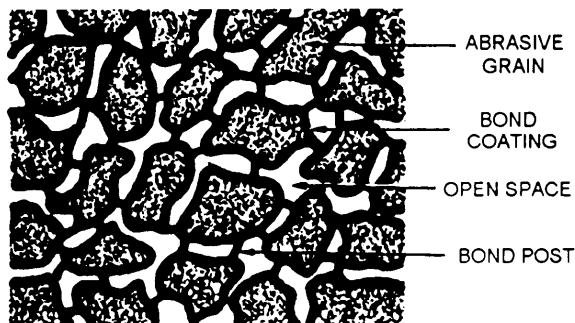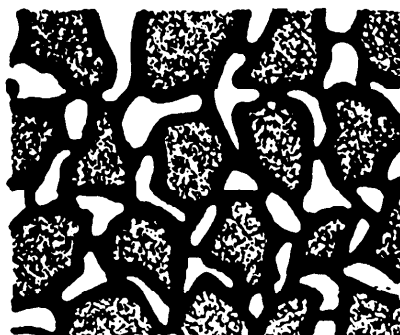

WHEEL A

03NVM061

WHEEL B

Figure 5-61.— How bond affects the grade of a wheel. Wheel

Grain Size.—The second section on the grinding wheel marking is the grain size. Grain sizes range from 10 to 600. The size is determined by the size of mesh of a sieve through which the grains can pass. Generally speaking, grain size is rated as follows: coarse: 10 through 24; medium: 30 through 60; fine: 70 through 180; and very fine: 220 through 600. Fine grain wheels are preferred for grinding hard materials, as they have more cutting edges and will cut faster than coarse grain wheels. Coarse grain wheels are generally preferred for rapid metal removal on softer materials.

Grade or Hardness.—Section three of the grinding wheel marking is the grade or hardness of the wheel. The grade is designated by a letter of the alphabet and it runs from A to Z or soft to hard. The grade of a grinding wheel is a measure of the bond's ability to retain the abrasive grains in the wheel. A soft to hard grade does not mean that the bond or the abrasive is soft or hard; it means that the wheel has either a large amount of bond (hard grade) or a small amount of bond (soft grade).

Figure 5-61 shows magnified portions of both soft-grade and hard-grade wheels. You can see that a part of the bond surrounds the abrasive grains, and the remainder of the bond forms into posts that hold the grains to the wheel and hold them apart from each other. The wheel with the larger amount of bonding material (hard grade) has thick bond posts and offers great resistance to grinding pressures. The wheel with the least amount of bond (soft grade) offers less resistance to grinding pressures.

Structure.—The fourth section of the grinding wheel marking is the structure. The structure is designated by numbers from 1 to 15. The structure of a grinding wheel refers to the open space between the grains, as shown in figure 5-61. Grains that are very closely spaced are said to be dense; when grains are wider apart, they are said to be open. Open grain wheels remove more metal faster than close-grain wheels. Also, dense, or close-grain wheels, normally produce a finer finish. Structure makes up about 20 percent of the grinding wheel.

Bond Type.—The fifth section on the grinding wheel marking is the bond type. The bond makes up the remaining 40 percent of the grinding wheel and is one of the most important parts of the wheel. The bond determines the strength of the wheel. The six basic types of bonds are vitrified, silicate, rubber, resinoid, shellac, and oxychloride. We will discuss each type in the following paragraphs.

VITRIFIED bonded wheels are designated by the letter *V*. They are not affected by oil, acid, or water. Vitrified bonded wheels are strong and porous, and rapid temperature changes have little or no effect on them. Do not run vitrified wheels faster than 6,500 surface feet per minute (sfpm).

SILICATE bonded wheels are designated by the letter *S*. Silicate bonded wheels are used mainly on large, slow rpm machines where a cooler cutting action is desired. Silicate bonded wheels are softer than vitrified wheels, and they release the grains more readily. Like the vitrified bonded wheel, do not run this wheel in excess of 6,500 sfpm.

RUBBER bonded wheels are designated by the letter *R*. These wheels are strong and elastic and they are used as thin cutoff wheels. These wheels are used extensively for regulating wheels on centerless grinders. Rubber bonded wheels produce a high finish and can be run at speeds up to 16,000 sfpm.

RESINOID bonded wheels are designated by the letter *B*. These wheels are shock resistant and strong and are used for rough grinding and cutoff wheels. Like rubber bonded wheels, you can run these wheels at speeds up to 16,000 sfpm.

SHELLAC bonded wheels are designated by the letter *E*. These wheels give a high finish and have a cool cutting action when used as cutoff wheels. Shellac bonded wheels can be run at speeds up to 12,500 sfpm.

OXYCHLORIDE bonded wheels are designated by the letter *O*. Do not run these wheels at speeds greater than 6,500 sfpm.

Manufacturer's Record.—The sixth section of the grinding wheel marking is the manufacturer's record. This may be a letter or number, or both. It is used by the manufacturer to designate bond modifications or wheel characteristics.

GRINDING WHEEL SELECTION AND USE

You should select a grinding wheel that has the proper abrasive, grain, grade, and bond for the job. You should base your selection on such factors as the physical properties of the material to be ground, the amount of stock to be removed (depth of cut), the wheel speed and work speed, and the finish required.

To grind carbon and alloy steel, high-speed steel, cast alloys, and malleable iron, you probably should use an aluminum oxide abrasive. A silicon carbide abrasive is most suitable for grinding nonferrous metals, nonmetallic materials, and cemented carbides.

Generally, you'll choose coarser-grain wheels to grind softer and more ductile the materials. Also use coarser-grain wheels to remove a large amount of material (except on very hard materials). If a good finish is required, a fine grain wheel should be used. For soft materials, small depth of cut, or high-work speed, use a soft grade wheel. If the machine you are using is worn, you may need to use a harder grade wheel to offset the effects of that wear. You also can use a harder grade wheel if you use a coolant with it. Table 5-3 lists recommended grinding wheels for

Table 5-3.—Recommendations for Selecting Grinding Wheels

OPERATION	WHEEL DESIGNATION					MATERIAL
	Abrasive	Grain size	Grade	Structure	Bond	
Cylindrical grinding	A	60	K	8	V	High-speed steel
	A	60	L	5	V	Hardened steel
	A	54	M	5	V	Soft steel
	C	36	K	5	V	Cast iron, brass, aluminum
	A	54	L	5	V	General purpose
Surface grinding	A	46	H	8	V	High-speed steel
	A	60	F	12	V	Hardened steel
	A	46	J	5	V	Soft steel
	C	36	J	8	V	Cast iron and bronze
	A	24	H	8	V	General purpose
Tool and cutter grinding	A	46	K	8	V	High-speed steel or cast alloy milling cutter
	A	54	L	5	V	Reamers
	A	60	K	8	V	Taps
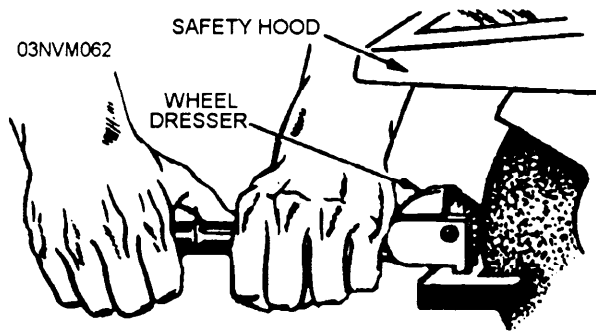
Figure 5-62.—Using a grinding wheel dresser.

various operations. However, before you perform these operations, you should be able to install and dress the wheels properly, whenever required.

WHEEL INSTALLATION.—The wheel of a pedestal grinder must be properly installed; otherwise, it will not operate properly and accidents may occur. Before you install a wheel, inspect it for visible defects and "sound" it by tapping lightly with a piece of hard wood to determine if it has invisible cracks. A good wheel will give out a clear ringing sound when tapped. If you hear a dull thud, the wheel is cracked and should not be used. When installing the wheel on the grinding machine, you should always refer to the technical manual to ensure that the wheel is correctly installed and tightened.
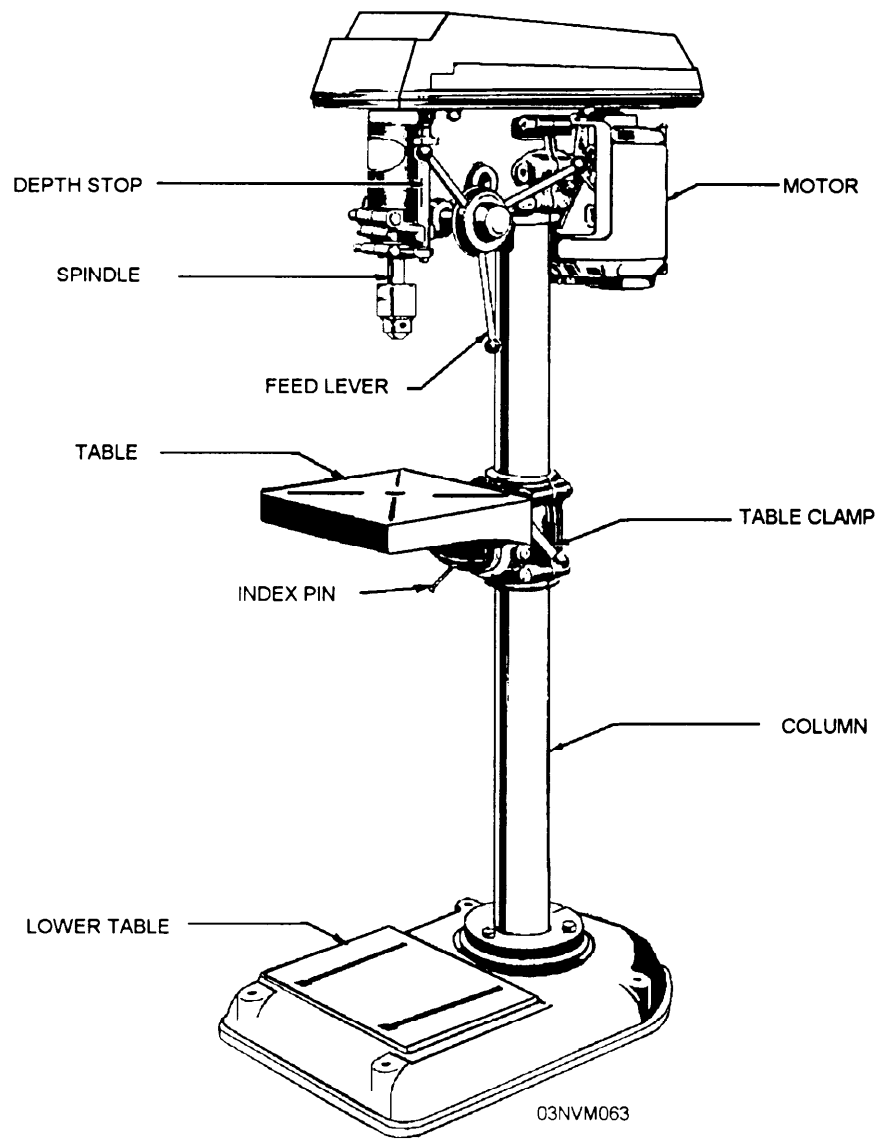
Figure 5-63.—Sensitive drill press.

TRUING AND DRESSING THE WHEEL.—Grinding wheels, like other cutting tools, require frequent reconditioning of cutting surfaces to perform efficiently. *Dressing* is the term used to describe the process of cleaning the periphery of grinding wheels. This cleaning breaks away dull abrasive grains and smooths the surface so that there are no grooves. *Truing* is the term used to describe the removal of material from the cutting face of the wheel so that the resultant surface runs absolutely true to some other surface such as the grinding wheel shaft.

The wheel dresser, shown in figure 5-62, is used for dressing grinding wheels on pedestal grinders. To dress a wheel with this tool, start the grinder and let it come up to speed. Set the wheel dresser on the rest as shown in figure 5-62 and bring it in firm contact with the wheel. Move the wheel dresser back and forth across the face of the wheel until the surface is clean and approximately square with the sides of the wheel.

Several things can get a grinding wheel out of balance. For instance, it may be out of roundness, and you can usually correct this problem by dressing the wheel. Or, it may get out of balance if part of the wheel is immersed in coolant. If this happens, remove and replace the wheel. If the wheel gets out of balance axially, it probably will not affect the efficiency of the wheel. To correct axial unbalance, simply remove the wheel and clean the shaft spindle, the spindle hole, and flanges.

Each time a wheel is dressed, you should check the clearance between the tool rest and the wheel. Reestablish the clearance at not more than 1/8 inch, as required. To preclude possible injury, make all adjustments with the machine secured.

DRILL PRESSES

There are many sizes and styles of drilling machines or drill presses, each designed for a particular type of work. Only the sensitive drill press and the radial drill press will be covered in this section.

One type of upright drill press is the sensitive drill press (fig. 5-63). It is used to drill small holes in work under conditions that make it necessary for the operator to "feel" what the cutting tool is doing. The tool is fed into the work by a very simple device-a lever, a pinion and shaft, and a rack that engages the pinion. These drills are nearly always belt-driven because the vibrations caused by gearing will reduce their sensitivity. The high-speed range of these machines and the holding devices used make them unsuitable for heavy work.

The radial drill press (fig. 5-64) has a movable spindle that can be adjusted to the work. This machine is especially useful when the workpiece is large, bulky, or heavy, or when you need to drill many holes with one setup, because the work does not have to be readjusted for each hole. The arm and spindle are designed so that the drill can be positioned easily over the layout of the workpiece.

Before operating any drill press, do a visual inspection to be certain that all parts are in the proper place, secure, and in good operating condition. Check all assemblies, such as the motor, head, pulleys, and bench for loose mountings. Check the V-belt and adjust it as necessary according to the manufacturer's technical manual. Make sure the electrical cord is securely connected and that the insulation is not damaged, chafed, or cracked.

While the drill press is operating, be alert for any sounds that signal trouble, such as squeaks or unusual noises. Report any unusual or unsatisfactory performance of the drill press to the petty officer in charge of the shop.

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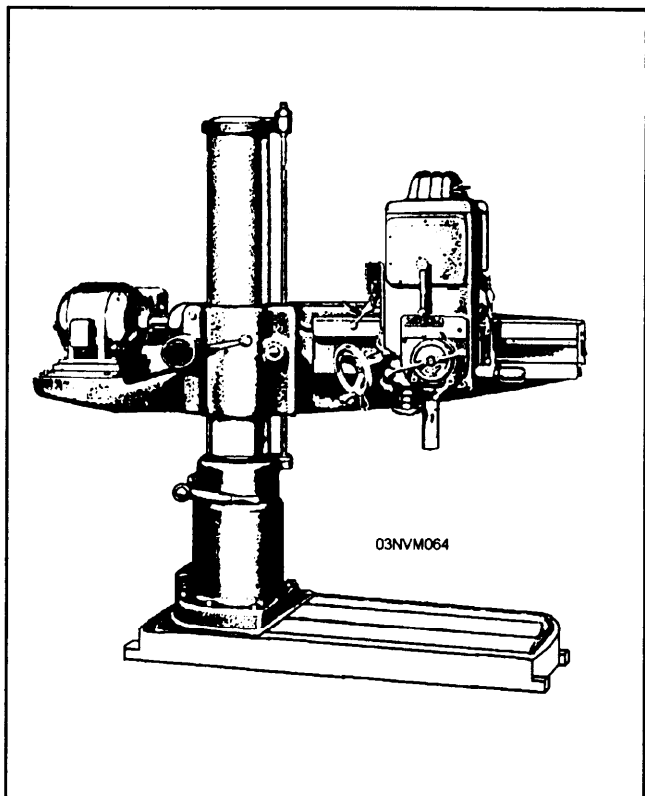
Figure 5-64.—Radial drill press.

You must use a cutting oil when drilling steel or wrought iron. Cast iron, aluminum, brass, and other metals may be drilled dry at high drilling speeds. However, you should use some medium to cool these metals. This will reduce the chances of overheating the drill bit and loss of the cutting edge. Compressed air may be used for cast iron; oleic acid for copper; sulphurized mineral oil for Monel; and water, lard, or soluble oil and soda water for ferrous metals. (Soda water reduces heat, overcomes rust, and improves the finish.)

After operating a drill press, wipe off all dirt, oil, and metal particles. Inspect the V-belt to make sure no metal chips are imbedded in the driving surfaces.

MAINTENANCE OF INSTALLED SHOP EQUIPMENT

The machines in your shop depend upon you for their care and maintenance. To keep your machines operating properly, you should perform PMS routinely. Preventive maintenance should be performed according to the Planned Maintenance System (PMS), described in *Military Requirements for Petty Officer Third Class,* NAVEDTRA 12044. PMS is minimum maintenance. If you feel more maintenance is required, refer to the technical publication and perform the necessary maintenance.

GAS CYLINDERS AND CYLINDER VALVES

You are required to know the standard Navy system for marking gas cylinders and to be able to identify the cylinder valves and cylinders of various gases. You should be familiar with the construction, design, and size of these cylinders. You should also know how to handle and stow gas cylinders in a safe and proper manner. This section will give you a few of the important facts about gas cylinders and cylinder valves. Additional information concerning compressed gases can be found in MIL-STD-101, *Color Codes for Pipelines and for Compressed Gas Cylinders.*

Figure 5-65.—Cutaway view of compressed gas cylinders: (A) Oxygen cylinder; (B) acetylene cylinder.

CONSTRUCTION OF CYLINDERS

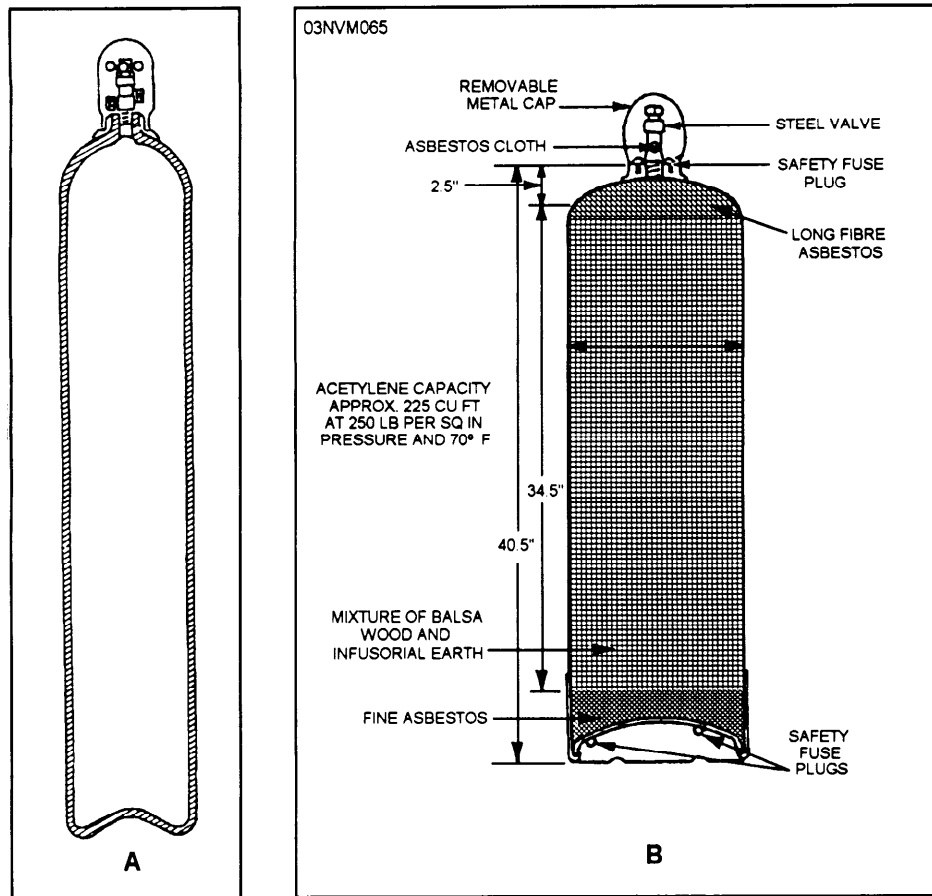Gas cylinders are made of high-quality steel. High-pressure gases, such as oxygen, hydrogen, nitrogen, and compressed air are stored in cylinders of seamless construction. Only nonshatterable high-pressure gas cylinders may be used by ships or activities operating outside the continental United States. Cylinders for low-pressure gases, such as acetylene, may be welded or brazed. All cylinders are carefully tested, either at the factory or a designated processing station, at pressures above the maximum permissible charging pressure.

The cylinders for most compressed gases are shaped alike. However, cylinders for acetylene are shorter and of a larger diameter, as shown in figure 5-65.

All gas cylinders have safety devices either in the valve, in the shoulder, in the bottom of the cylinder, or in a combination of these places. A threaded valve protection cap screws on the neck ring and protects the valve.

MARKING AND IDENTIFYING GAS CYLINDERS

Gas cylinders are manufactured and maintained according to the regulations of the Interstate Commerce Commission (ICC). The ICC stipulates that each cylinder be indented or stenciled with prescribed identification markings. Cylinders larger than 2 inches in diameter must be indented with serial numbers. Therefore, cylinders exceeding 2 inches in diameter, which are not assigned Navy serial numbers, require manufacturer's serial numbers. No more than 500 cylinders are allowed in each lot manufactured. Requirements for ICC 8 (acetylene) and ICC 9 (aerosol dispenser) cylinders are exceptions to this requirement. ICC 8 cylinders of all sizes require serial numbers and ICC 9 cylinders of all sizes are assigned lot numbers. However, an unlimited number per lot is authorized.

Navy-owned compressed-gas cylinders are indented with figures and letters. In addition to the identifications required by ICC regulations, Navy-owned cylinders for gases in the liquid state with a water capacity in excess of 15 pounds, or gases in the gaseous state with a volume in excess of 658 cubic inches, are identified by an indented Navy serial number. This number is preceded and followed by the letters USN. Acetylene cylinders contain acetylene dissolved in acetone, and are assigned Navy serial numbers on the volume basis. In other words, gases in the liquid state are measured by weight, and those in the gaseous state are measured by volume. Acetylene, though dissolved in a liquid, is measured as a gas by volume.

Since 1 August 1944, Navy serial numbers have a designated letter placed before the numerals. This letter shows the type of gas carried in the cylinder. The lettering system assigns the following letters to the gases:

A—Acetylene

M—Ammonia

D—Carbon dioxide

K—Chlorine

E—Ethylene oxide

H—Helium

N—Nitrogen

J—Nitrous oxide

G—Aerosol

X—Oxygen

P—Liquefied petroleum gas (propane, butane, and so on)

S—Sulfur dioxide

F—Freon

B—Carboxide

Y—Hydrogen

R—Methyl chloride

Z—Compressed air

L—Ethyl chloride

NO—Nitrogen dioxide

V—Argon

In addition to markings required by the ICC, gas cylinders used by all three services—Navy, Army, and Air Force—have certain standard identifying features. So much injury and damage can be, and has been, caused by mistaking one gas cylinder for another. Therefore, a national program has been established to make it almost impossible to confuse cylinders. The identifying features used by the Armed Forces in this program consist of using a color code for painting the cylinders, stenciling the name of the

gas along two sides of the cylinder, and placing two identifying symbols (decals) on the shoulder of each cylinder. The gas cylinders must be painted as shown in figure 5-66, and the arrangement of colors will appear as shown in table 5-4.

If the color of the cylinders reduces the effectiveness of the ship's camouflage scheme, canvas covers painted with the camouflage colors should be placed over the cylinders. Do not paint the cylinders with camouflage paint.

Shatterproof cylinders are stenciled in two locations with the phrase "Non-Shat" lengthwise and 90° from the titles. Letters must be either black or white, and approximately 1 inch in size.

Color Codes for Cylinders

Color coding is mandatory for compressed-gas cylinders. Identifying colors are assigned by the Standardization Division, Office of the Assistant Secretary of Defense (Supply and Logistics).

LOCATION OF COLORS ON GOVERNMENT - OWNED CYLINDERS

LOCATION OF COLORS ON COMMERCIAL - OWNED CYLINDERS

LOCATION DIMENSIONS

ON CYLINDERS FOR MEDICAL GAS MIXTURES, 1" SPACE AND BAND C ARE LOCATED IMMEDIATELY BELOW BANDS B' OR B"

CYLINDERS FOR	OVERALL LENGTH	SHOULDER COLOR(S)			CYLINDER COLOR BAND (S)				COMMERCIAL IDENTIFICATION
		A	A'	A"	B	B'	B"	C	D
MEDICAL GAS MIXTURE	OVER 30"	L/5	3 1/2"	—	—	A LESS 3 1/2"	—	3"	L/6
OTHER GASES	"	L/5	—	—	3	—	—	3"	L/6
MEDICAL GAS MIXTURE	30" AND UNDER	L/5	—		—	—	A LESS A"	2"	L/6
OTHER GASES	"	L/5	—	—	2	—	—	2"	L/6

FROM CYLINDERS TOP TO BOTTOM OF NECK RING

NOTE 1" SPACE TO BE OMITTED IF BANDS B & C ARE OF DIFFERENT COLORS

Figure 5-66.—Location of color codes on gas cylinders.

Table 5-4.—Cylinder Color Code

Contents of cylinder	Location of cylinder markings			
	Top A	B and B	B and C	Body
Medical anesthetic gases:				
Cyclopropane.	Orange	Yellow	Blue	Blue
Ethylene.	Yellow	Blue	Blue	Blue
Nitrous oxide	Blue	Blue	Blue	Blue
Fuel gases:				
Acetylene	Yellow	Yellow	Yellow	Yellow
Hydrogen	Yellow	Black	Yellow	Yellow
Manufactured gases.	Brown	Yellow	Yellow	Yellow
Petroleum (liquefied & nonliquefied)	Yellow	Orange	Yellow	Yellow
Industrial gases:				
Butadiene.	Yellow	White	Buff (tan)	Buff (tan)
Ethylene oxide	Yellow	Blue	Buff (tan)	Buff (tan)
Ethyl chloride	Buff	Blue	Yellow	Buff (tan)
Propylene.	Yellow	Gray	Buff	Buff (tan)
Vinyl chloride	Yellow	Orange	Buff	Buff (tan)
Vinyl methyl ether.	Yellow	Black	Buff	Buff (tan)
Aerosol insecticide.	Buff	Buff	Buff	Buff (tan)
Toxics and poisonous materials:				
Carbon monoxide.	Yellow	Brown	Brown	Brown
Hydrogen sulfide	Brown	Yellow	Brown	Brown
Methyl bromide.	Brown	Black	Brown	Brown
Boron trifluoride	Gray	Brown	Brown	Brown
Chlorine	Brown	Brown	Brown	Brown
Hydrogen chloride	Brown	White	Brown	Brown
Phosgene	Brown	Orange	Brown	Brown
Sulfur dioxide	Brown	Gray	Brown	Brown
Refrigerants:				
Ammonia	Brown	Yellow	Orange	Orange
Freons	Orange	Orange	Orange	Orange
Methyl chloride.	Yellow	Brown	Orange	Orange
Oxidizing gases:				
Oxygen, aviator's	Green	White	Green	Green
Air, oil pumped	Black	Green	Green	Black
Air, water pumped	Black	Green	Black	Black
Helium-oxygen.	Buff	White	Green	Green
Oxygen-carbon dioxide	Gray	White	Green	Green
Inert gases:				
Argon, oil pumped	Gray	White	White	Gray
Argon, water pumped.	Gray	White	Gray	Gray
Carbon dioxide.	Gray	Gray	Gray	Gray
Helium, oil pumped.	Gray	Orange	Gray	Gray
Helium, oil free	Buff	Gray	Gray	Gray
Nitrogen, oil pumped	Gray	Black	Gray	Gray
Nitrogen, water pumped.	Gray	Black	Black	Gray
Fire-fighting gases:				
Carbon dioxide.	Red	Red	Red	Red
Methyl bromide.	Red	Brown	Red	Red

Cylinders that have a background color of yellow, orange, or buff have the title stenciled in black. Cylinders that have a background color of red, brown, black, blue, gray, or green have the title stenciled in white. Figure 5-67 shows how cylinders are identified by the overall painted color code and by the stenciled name of the gas.

Decalcomanias

As a further identification measure, two decalcomanias (pronounced de-kel-ko-main-e-ah, or abbreviated as decals), are applied to the shoulder of each cylinder. The decals show the name of the gas and the precautions for its handling and use. The decals are available from general stores for each gas used in the Navy.

TESTING AND REPAIRING CYLINDERS

ICC regulations require that all gas cylinders, except acetylene cylinders, be retested every 5 years. Cylinders that are due for retesting are not to be charged and shipped until such retests have been properly made. However, cylinders that have been charged before the expiration of their retest period may be shipped and used until empty. They will then be turned in for retesting. The dates of retests are permanently and plainly marked by the stamping on the shoulder of the cylinder, directly opposite the ICC and Navy serial numbers. The stamping, for example 4-88, means that the last test was performed in April 1988.

The 5-year tests are performed by naval activities and civilian agencies under regulations of the ICC. Personnel aboard naval ships are not authorized to perform such tests. Empty cylinders with expired test periods should be returned to the nearest naval supply depot or cylinder testing activity, and marked "For Retest."

HANDLING AND STOWING CYLINDERS

You must always remember ALL compressed gases are hazardous. Many detailed precautions could be set down with regard to the handling and stowing of these gases. The more important ones are summarized in this section.

The term *stowage* as used in the following paragraphs refers to articles under the cognizance of the supply officer, in general stores, to be drawn on for the ship's own use, or articles of cargo being
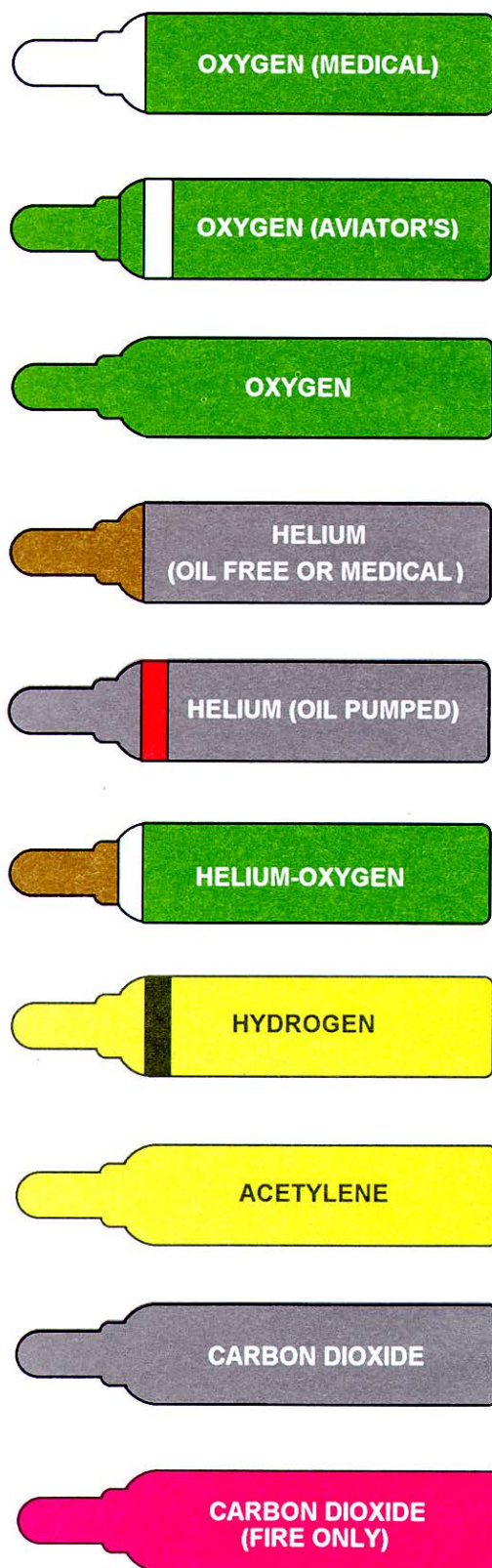

Figure 5-67.—Identifying color patterns for gas cylinders.

transported. It does not refer to cylinders that have been removed from stores or from cargo and transferred to the shops or other locations for use.

The term *ready service* refers to cylinders or other articles that have been transferred from stores and are actually located in a shop or near a place where they are to be used. It is not necessary that the articles be in actual use, but they must be ready for use.

Handling Cylinders

Cylinders that contain flammable and/or explosive gases must be handled with extreme care. Every effort should be made to avoid dropping them or allowing them to strike too hard against each other or any other object. Take every precaution to prevent bumping or striking the discharge valves.

When cylinders are being handled, the cylinder valve outlet cap and the cylinder valve protecting cap must be in place. Unless ready-service cylinders are secured in special portable racks, regulators must be removed and caps replaced before the cylinders are moved to a new location. Even then, it is best to remove the regulators and replace the caps for safety.

Be very careful when loading or transferring cylinders, especially when using a crane or derrick. The cylinders must be secured in a cradle, suitable platform, rack, or special container such as a sandbag. Electromagnets must never be used. A cylinder moved by hand should be tilted slightly and rolled on its bottom edge, without dragging or sliding. Hooks or lines through the valve protection cap must not be used for hoisting cylinders. Cylinders frozen to the deck, or otherwise fixed, must not be pried loose with crowbars or similar tools.

When gas cylinders are transported on a hand truck, they must be held securely in position. The truck should be fastened to a bulkhead or stanchion as soon as the destination is reached. The truck should be constructed as follows:

— Frame sufficiently rigid to permit handling with tackle.

— Grips or handles ending in a vertical line with the aft side of the wheels. (This facilitates fastening to a bulkhead.)

— Platform fitted with sides to prevent the cylinders from sliding off.

— Metal strap clamps provided for retaining the tops of the cylinders in place. Chains are not to be used as retainers since they normally are a little slack; the cylinders can shift and cause an accident.

Stowage of Compressed Gases

In general, weather-deck stowage will be provided for flammable and explosive gases. However, in specific cases, below-deck stowage is approved; depending on the particular type, mission, and arrangement of the ship. In such cases, these approved locations are shown on the ship's plans.

Compressed gases aboard all ships, except cargo ships, should be stowed only in compartments designated by NAVSEA, as shown in applicable plans for the ship. In such cases, the following precautions must be observed:

● Take necessary steps to keep the maximum temperature of the stowage compartment below 130°F.

● When provisions are made for mechanical ventilation, operate this ventilation according to the damage control classification assigned. The classification for closures of this system are either "Z, " "W," or "W."

● Do not install portable electric wiring and equipment in compartments designated for the stowage of flammable or explosive gases.

● Keep flammable materials, especially grease and oil, out of the stowage space.

● Securely fasten each cylinder individually, in the vertical position (valve end up), by metal collars. Other arrangements are approved for cargo ships fitted especially for cylinder transport.

● Stow oxygen and chlorine in compartments separate from flammable gases. Inert or non-flammable gases may be stowed in any compartment designated for compressed gas stowage.

● Ventilate compartments containing compressed gases for 15 minutes before entry in the event that ventilation has been closed down. A suitable sign to this effect should be posted on the outside of the access door.

When compressed gas is stowed on the weather deck, the following additional precautions must be observed:

● Do not stow oxygen and chlorine cylinders close to the fuel-gas cylinders. Normal practice is to stow gas cylinders on one side of the ship and to stow oxygen and chlorine cylinders on the other side.

● Stow cylinders containing compressed gases for the greatest possible protection. During the winter, protect cylinder valves against the accumulation of snow and ice. Use warm water (not boiling) to thaw ice accumulations in cylinder valve caps and outlets. Boiling water may melt the fusible plugs. During the summer, screen cylinders from the direct rays of the sun.

● Make every effort to prevent corrosion of threaded connections of cylinders that are stowed for extended periods of time. The use of grease, lubricants, or flammable corrosion inhibitors on oxygen cylinders is NOT permitted. Oil or grease in the presence of oxygen under pressure will ignite violently.

● The stowage area should be as far away as practical from navigation stations, fire control stations, and gun mounts.

Ready-Service Storage Rules

Cylinders in actual use, and those attached to welding, fire fighting, medical, refrigeration, or similar apparatus, ready for use, are permitted below decks outside of the stowage compartment.

The following special precautions must be taken with oxygen and fuel-gas cylinders for welding:

● The number of cylinders of gas needed to equip each authorized gas cutting and welding position may be installed in shops. The number of authorized positions will be determined from either a NAVSEA-approved plan or the machinery specifications for the shop concerned.

● Securely fasten cylinders in a rack. The rack must be securely fastened to the bulkhead, and must not allow any vertical movement of cylinders.

● Stow cylinders attached to NAVSEA-approved damage control equipment below decks in repair lockers. Spare cylinders used for this purpose may be stowed in the same locations.

● Remove welding units from the designated stowage location to perform work at some remote location in the ship. Return these units to the designated stowage location immediately after you complete your work. Attend to the equipment at all times while it is away from its regular stowage.

● Post a card showing the following warning at the designated stowage location of each unit:

WARNING: UNIT IS NOT SECURE WHILE PRESSURE SHOWS ON GAUGES, OR WHEN CYLINDERS ARE NOT FIRMLY FASTENED TO RACK OR TO BULKHEAD, OR WHEN RACK IS NOT FIRMLY FASTENED TO BULKHEAD. IF REMOVED FROM THIS LOCATION, THIS UNIT IS TO BE CONSTANTLY ATTENDED UNTIL RETURNED AND SECURED.

● Attach a card showing the following statement to each unit:

RETURN TO (DESIGNATED LOCATION) IMMEDIATELY ON COMPLETION OF WORK. UNIT SHALL NOT BE LEFT UNATTENDED WHILE AWAY FROM ABOVE LOCATION. UNIT IS NOT SECURE WHILE PRESSURE SHOWS ON GAUGES, OR WHEN CYLINDERS ARE NOT FIRMLY FASTENED TO RACK OR BULKHEAD, OR WHEN RACK IS NOTFIRMLY FASTENED TO BULKHEAD OR STANCHION.

See *NSTM,* chapters 550 and 074, volume 3, for detailed precautions.

DISPOSITION OF EMPTY CYLINDERS

Empty cylinders should be delivered to the nearest naval supply depot. Valves should be closed and under some positive pressure, except where the design of the valve does not permit closing, as is the case with fire extinguishers. The pressure is necessary to prevent condensation of atmospheric moisture on the internal walls. In the case of acetylene cylinders, the pressure prevents loss of the solvent (acetone) and/or entry of

air, if the cylinders cool considerably below the temperature at which they were discharged.

Sometimes, cylinders used for aviator's breathing oxygen, dry nitrogen, argon, or dry air are found to have open valves and/or a positive internal pressure of less than 25 psi. These cylinders should be tagged with the explanation that they must be dried before they are refilled.

GAS CYLINDER VALVES

Navy standard gas cylinder valves are of two basic designs: packed valves and diaphragm-type packless valves.

Packed valves require a packing material around the valve stem to prevent leakage. The valve stem is packed to prevent gas from leaking out around the stem when the valve is open. MIL-V-2 covers the authorized packing material for gas cylinder valves.

Packless valves are sealed against leakage around the valve stem by flexible metallic diaphragms securely clamped to the valve bonnets. The basic packless design may be classified into two types: nonbackseating and backseating. The nonbackseating type is designed so that the metallic sealing diaphragms may not be replaced under pressure. In the backseating type the metallic diaphragms may be replaced without undue hazard or loss of contained gases if the outlet cap is in place and secure. Diaphragms in packless valves should be replaced only by activities carrying spare diaphragms specifically designed for the valves in need of reconditioning.

These diaphragms are made from materials selected for service at varying high pressures. In addition, they are often designed only for use with valves built by a given manufacturer and for a specific gas.

The Navy gas valve program (and concerned civilian agencies) provides noninterchangeable valve outlets and connections for different gases to prevent the use of the wrong gas at any time.

Construction and Identification of Valves

Valves designed to control the flow of compressed gases are forged of brass, bronze, or steel, and are made in various shapes and sizes. Figures 5-68 and 5-69 show typical gas cylinder valves. The valves are opened and closed with either hand-operated or wrench-operated spindles. When the valves are open,
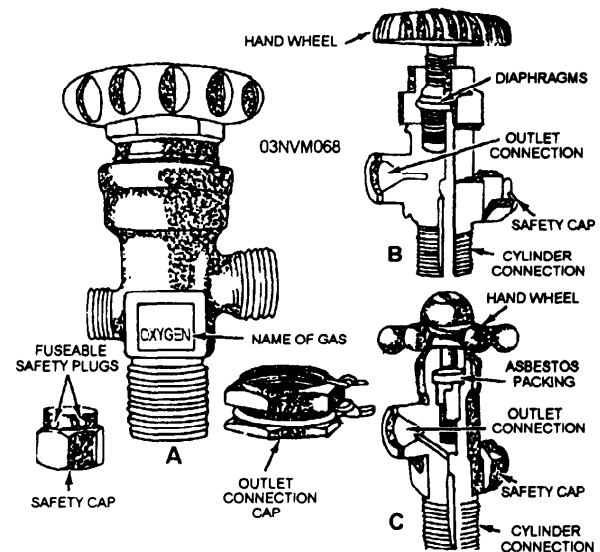

Figure 5-68.—Oxygen cylinder gas valves: (A) external view of one type of valve, with related safety and outlet connection caps; (B) cutaway view of the same valve, showing diaphragms to prevent gas leakage when the valve is opened; (C) cutaway view of another type of valve, with asbestos packing to prevent gas leakage when the valve is opened.

gas flows through a threaded male cylinder connection into the valve body and past the valve outlet connection into the pressure regulator. (Pressure regulators reduce the pressure of compressed gases from the cylinder pressure to the desired working
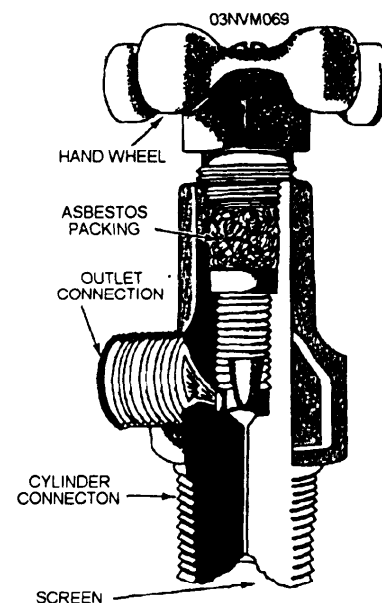

Figure 5-69.—Cutaway view of an acetylene cylinder valve showing asbestos packing.

5-47

pressure. All regulators are marked with the name of the gas for which they are intended.)

To prevent leakage of gas above the valve stem when the valve is opened, each valve is equipped with asbestos, leather, rubber packing, or metal diaphragms. Most valves have safety devices. (The safety devices for acetylene and ammonia are in the cylinders rather than in the valves.) These safety devices consist of fusible metal plugs, rupture disks, or both. Spring-loaded safety devices are used for some gases. If heat causes too much pressure, the fuse plugs melt and the disks burst, releasing the contents of the cylinder. Acetylene valves have screens in the cylinder connections; other valves do not.

Valves manufactured according to the latest military specifications have the name of the gas, or service for which they are designed. indented on at least one of the flats on the sides of the valves. Valves must be used only for the gases or fluids indicated. Otherwise, personnel may be injured or the equipment may be damaged.

Safety Devices for Valves

Military specifications and ICC regulations require that valves designed for certain services be fitted with safety devices. These devices guard against a buildup of hazardous pressures caused by heat. This can easily happen with CO_2 cylinders used for fire fighting in fire rooms and engine rooms. Pressure can also build up from overcharging or similar causes. These safety devices may be divided into four general categories based on functional design as follows:

1. FUSIBLE PLUGS—A fusible plug may be described as a threaded hex-head plug with a center filled with fusible metal. When the cylinder is overheated, the fusible metal melts and permits the gas to escape. This type of device is used on chlorine, freon, acetylene, and such gases.

2. SPRING-LOADED SAFETY DEVICE— These devices usually function as "pop" valves that open to release excess pressure when pressure in the cylinder overcomes spring tension. Devices of this sort are used on liquefied petroleum gas valves. They operate generally at about 150 percent of the cylinder's ICC-approved pressure.

3. UNBACKED SAFETY CAP WITH RUPTURE DISK—This safety device is essentially a safety cap that covers a safety port in the valve. The cap retains a breakable disk firmly over the safety port.

Pressures ranging from 2,600 to 3,000 psi will rupture the safety disk and allow the gas in the cylinder to vent to the atmosphere. This type of safety device is used in carbon dioxide service.

4. BACKED SAFETY CAP WITH RUPTURE DISK—Backed safety caps with rupture disks are essentially the same as those described in paragraph 3. However, the breakable disk is supported by fusible metal contained in the safety cap thus blocking off escape ports. This cap works when the cylinder, valve, and therefore the fusible metal are heated above the melting temperature. When the pressure within the cylinder reaches 2,600 to 3,000 psi, the breakable disk ruptures and reduces the pressure. This type of device is used commonly on air, argon, helium, hydrogen, nitrogen, and oxygen valves.

Lea king Valves

Cylinders with leaking or defective valves should be tagged as such and turned in to the nearest naval supply depot for overhaul.

Safety Precautions

Cylinders, regulators, hoses, and torches are important parts of the shop equipment for heating, welding, and cutting. Learn and follow these safety rules for this type of equipment:

● Never fill a cylinder with a gas other than the gas for which it is specifically designated. Never remove or change the decals.

● Never return an empty cylinder without making sure that valves are closed and that protective caps are in place.

● Never drop the cylinders or let them strike against each other.

● Never use cylinders as rollers or supports.

● Never hammer or strike the valve wheel to open or close the valve. Use only the wrenches or tools approved for that purpose.

● If valve outlets are iced, use only warm water to free them. Never use hot or boiling water.

● Never use a cylinder that IS improperly marked; that is, where the paint color doesn't agree with the information on the decal.

- Never use a lifting magnet or a sling to raise or handle a cylinder.

- Be careful not to mix full and empty cylinders in a stowage rack.

- Never tamper with safety devices on the valves or cylinders.

- Never store oxygen and acetylene cylinders in the same immediate area.

- Be especially careful that you never strike an arc on gas cylinders or sealed metal cylinders of any kind.

- Acetylene and low-pressure fuel-gas cylinders, which have been stowed in a horizontal position, must be placed in a vertical position for at least 2 hours before you use them. This will allow the porous filler material inside the cylinder to settle.

SUMMARY

This chapter gave you a brief introduction to the handtools, power tools, and installed equipment used by HTs. The importance of caring for these tools properly cannot be stressed enough. Learn to use them correctly and protect them from loss or damage. These tools will determine how well you perform your job.

Now you also have an understanding of the operations and safety precautions of portable hand and power tools, pneumatic tools, grinders, drilling machines, bandsaws, power hacksaws, and thread-cutting tools. However, it would be to your advantage to read the manufacturers' operating manuals for all of shop tools and equipment. You should also review the section on compressed-gas cylinders and the safety precautions involved with them. You will find that you will work with some aspect of compressed-gas cylinders almost every day.

CHAPTER 6

METALLURGY

LEARNING OBJECTIVES

Upon completion of this chapter; you will be able to do the following:

● *Explain the concepts of stress and strain in metals.*

● *Describe the different properties of metals.*

● *Identify the two major classes of metals.*

● *Describe the different types offerrous and nonferrous metals.*

● *Identify different metals by color markings, surface appearance, and identi-fication tests.*

INTRODUCTION

As an HT, you will be working with many different types of metals and alloys. The more knowledge you have of metals and alloys, the better you will be able to perform your repair and maintenance duties. You should have some accurate means of identifying metals. To intelligently solve welding problems, you should also have a good understanding of the internal structure of metals, and the effects that welding (heat input) has on metals. This chapter will start you on your way by giving you a basic understanding of metallurgy.

Can you define a metal? Chemical elements are considered to be metals if they are lustrous, hard, good conductors of heat and electricity, malleable, ductile, and heavy. Some metals are heavier than others; some are more malleable than others; and some are better conductors of heat and electricity. These properties are known as "metallic properties," and chemical elements that possess these properties to some degree are called metals. Chemical elements that do not possess these properties are called nonmetals. Oxygen, hydrogen, chlorine, and iodine are examples of nonmetallic chemical elements.

Chemical elements that behave sometimes like metals and sometimes like nonmetals are often called metalloids. Carbon, silicon, and boron are examples of metalloids.

An alloy may be defined as a substance that has metallic properties and is composed of two or more

elements. The elements that are used as alloying substances are usually metals or metalloids. By combining metals and metalloids, it is possible to develop alloys that have the particular properties required for a given use.

Table 6-1 lists some common metals and metalloids and gives the chemical symbol that is used to identify each element.

Table 6-1.—Symbols of Common Metals and Metalloids

Element	Symbol
Aluminum	A1
Antimony	Sb
Cadmium	Cd
Carbon	C
Chromium	Cr
Cobalt	Co
Copper	Cu
Iron	Fe
Lead	Pb
Magnesium	Mg
Manganese	Mn
Molybdenum	Mo
Nickel	Ni
Phosphorus	P
Silicon	Si
Sulfur	S
Tin	Sn
Titanium	Ti
Tungsten	W
Vanadium	V
Zinc	Zn

CARBON STEEL is an alloy of iron and controlled amounts of carbon. ALLOY STEEL is a combination of carbon steel and controlled amounts of other desirable metal elements.

The percentage of carbon content determines the type of carbon steel. For example, wrought iron has 0.003 percent carbon, meaning three thousandths of one percent. Low-carbon steel contains less than 0.30 percent carbon. Medium-carbon steel varies between 0.30 and 0.55 percent carbon content. High-carbon steel contains approximately 0.55 to 0.80 percent carbon, and very-high-carbon steel contains between 0.80 and 1.70 percent carbon. Cast iron contains 1.8 to 4 percent carbon.

Carbon generally combines with the iron to form CEMENTITE, a very hard, brittle substance. Cementite is also known as IRON CARBIDE. This action means that as the carbon content of the steel increases, the hardness, the strength, and the brittleness of the steel also tend to increase.

Various heat treatments are used to enable steel to retain its strength at the higher carbon contents, and yet not have the extreme brittleness usually associated with high carbon steels. Also, certain other substances, such as nickel, chromium, manganese, vanadium, and other alloying metals, may be added to steel to improve certain physical properties.

A welder must also have an understanding of the impurities occasionally found in metals and their effect upon the weldability of the metal. Two of the detrimental impurities sometimes found in steels are phosphorus and sulphur. Their presence in steel is due to their presence in the ore, or to the method of manufacture. Both of these impurities are detrimental to the welding qualities of steel. Therefore, during the manufacturing process, extreme care must always be taken to keep the impurities at a minimum (0.05 percent or less). Sulphur improves the machining qualities of steel, but it is detrimental to its hot forming properties.

During a welding operation, sulphur or phosphorus tends to form gas in the molten metal. The resulting gas pockets in the welds cause brittleness. Another impurity is dirt or slag (iron oxide). The dirt or slag is imbedded in the metal during rolling. Some of the dirt may come from the by-products of the process of refining the metal. These impurities may also produce blow holes in the weld and reduce the physical properties of the metal in general.

When external force is applied to any solid material, the material is subjected to stress. Many of the properties of metals can best be understood in terms of the manner in which they react to stress. Therefore, before considering the properties of metals and alloys, let us examine the concepts of stress and strain.

Load, which is usually measured in pounds, is the external force applied to a material. When the load is applied, reaction forces to the load occur throughout the material. The reaction forces are stresses. Why do these forces occur when a load is applied to a material? Newton's third law of motion states that "to every force or action, there is an equal and opposite reaction." Stress, therefore, is the "equal and opposite" reaction to the externally applied load. It is defined as the force per unit area resisting the load. Unit area is important. The unit area may be stated as a square inch, a square foot, or any other predetermined amount of area that is used to figure the amount of stress that the material will be subjected to. When the load is applied, it is distributed equally throughout the cross section of the material. For example, suppose two round metal rods with cross-sectional areas of 1 square inch and 2 square inches are each supporting a 2000-pound weight. The load or external force is the same on both, but since the cross-sectional areas are different and the load is distributed equally over the cross-sectional areas, the stresses in the two rods are also different.

You can see from the example that the stress is equal to the load divided by the cross-sectional area. That is, equal portions of the load are distributed equally over the cross-sectional area. Stress is usually measured in pounds (for load) per square inch (for area). Conversely, the load can be determined by multiplying the stress by the cross-sectional area.

Strain is the deformation or change in shape caused by the load. Some strain always occurs as a reaction to a load. The amount of strain depends on the magnitude and duration of the stress caused by the load. It also depends on the type and condition of the material. Strain is measured in inches per inch or in percentage. Thus, when a load is applied to a bar in tension, the bar will elongate (be strained) some fraction of an inch for each inch of bar (the strain will be the same in each inch of bar). If strain is being measured in percentage, the bar will be elongated a certain percentage; that is, the total length of the bar will be

increased a certain amount, which will be a percentage of the original length.

Stress occurs because molecular forces within the material resist the change of shape that an applied load tends to produce. In other words, stress results from the resistance of the molecules to being shifted around, pulled apart, or squeezed together. Because stress involves molecular forces, a piece of metal that is subjected to a load develops an enormous number of stresses, rather than just one stress. If you had more than a very few molecules, you would have to draw thousands or perhaps millions of arrows to indicate all the molecular forces involved. We often speak of stress as though it were one internal force, acting in one direction; that is, the direction opposite to the direction of the applied load. In other words, we consider the TOTAL EFFECT of all the molecular stresses, rather than trying to consider each set of molecular stresses separately.

The manner in which the load is applied determines the type of stress that will develop. Applied forces are usually considered as being of three basic kinds: tension (or tensile) forces, compression forces, and shearing forces. The basic stresses, therefore, are tension (or tensile) stresses, compression stresses, and shearing stresses. Complex stresses such as bending stresses and torsional stresses are combinations of two or more of the basic stresses.

TENSION STRESS

Tension stresses develop when a material is subjected to a pulling action. If, for example, a cable is fastened to an overhead clamp and a weight is attached to the free end, tension stresses develop within the cable. The tension stresses resist the tension forces that tend to pull the cable apart. Figure 6-1 shows tension forces and the resulting "equal and opposite" tension stresses.

COMPRESSION STRESS

Compression stresses develop within a material to oppose the forces that tend to compress or crush the material. A column that supports an overhead weight is said to be in compression, and the internal stresses that develop within the column are compression stresses. Figure 6-2 shows compression forces and compression stresses.
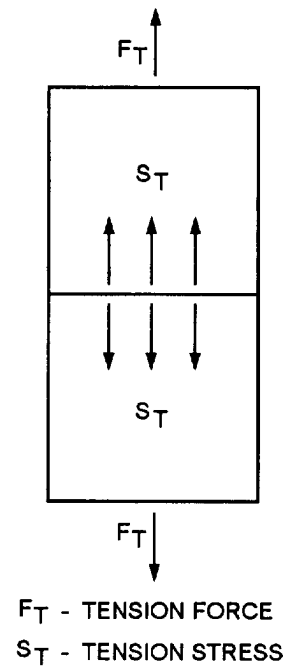

F_T - TENSION FORCE
S_T - TENSION STRESS

Figure 6-1.—Tension forces and tension stresses.

F_C - COMPRESSION FORCE
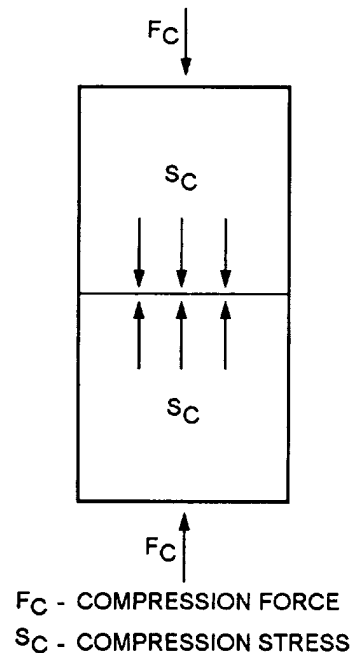S_C - COMPRESSION STRESS

Figure 6-2.—Compression forces and compression stresses.

SHEARING STRESS

Shearing stresses develop within a material when opposite external forces are applied along parallel lines in such a way as to tend to cut the material. Shearing forces tend to separate material by sliding

part of the material in the opposite direction. The action of a pair of scissors is an example of shear forces and shear stresses. The scissors apply shear forces, and the material being cut resists the shear forces by its internal shear stresses. Forces tending to produce shear in a rivet are illustrated in figure 6-3. Shear stresses are not shown, since they are considerably more complex than tension stresses and compression stresses.

BENDING STRESS

Bending stresses develop when a material is subjected to external forces that tend to bend it. When a load is applied to a beam, for example, as shown in figure 6-4, the upper surface is in compression and the lower surface is in tension. The NEUTRAL AXIS, indicated by the broken line in figure 6-4, is neither in compression nor in tension.
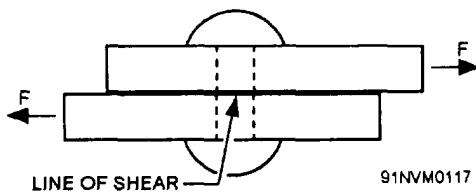

Figure 6-3.—Shearing forces applied to a rivet.
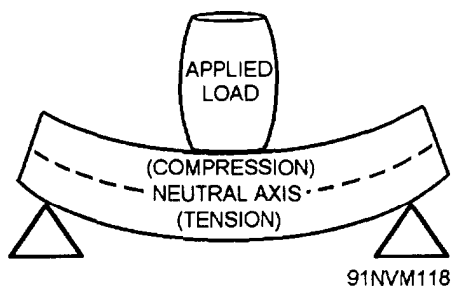

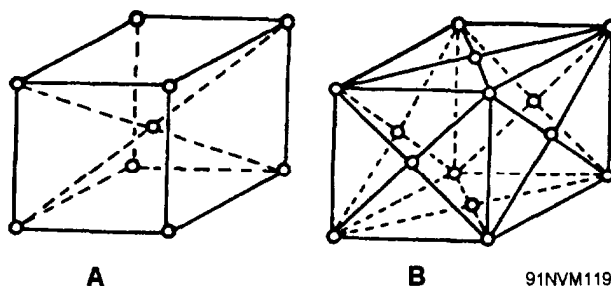Figure 6-4.—Load applied to a beam.

Figure 6-5.—Crystal structure of iron. A. Body-centered cubic, 9-atom space lattice. B. Face-centered cubic, 14-atom space lattice.

TORSIONAL STRESS

Torsional stresses develop in a material when external forces are applied in such a way that they tend to produce rotation. A ship's shaft, for example, rotates when the external applied forces are greater than the internal torsional stresses developed in the shaft. Torsional stress is primarily a special form of shear stress, although it may also involve some compression stress and some tension stress.

INTERNAL STRUCTURE OF METALS

The atoms in all solid metals are arranged in some definite geometric (or crystallographic) pattern. The smallest grouping of atoms that has the complete symmetrical arrangement of the crystal is called a unit cell. The regular arrangement of these atoms is called a space lattice. A unit cell is much too small to be seen. When a great many unit cells are combined, however, they form a visible crystal that has the same geometric structure as the unit cell.

A number of different geometrical arrangements of atoms are possible, but most metals have space lattices that are basically shaped like cubes, tetragons, or hexagons. Figure 6-5 shows the body-centered cubic and face-centered cubic space lattices.

How do crystals form? When the metal is in the liquid state, the atoms move freely and are not arranged in any orderly fashion. When the metal begins to cool, however, the atoms move more and more slowly. When the freezing (solidifying) temperature of the metal is reached, the atoms begin to form unit cells of the type characteristic of the particular metal. In this crystallization process, the atoms give up energy in the form of heat. As this energy flows from the metal, other atoms form around each of the original unit cells in a definite pattern. This definite and repeating pattern upon solidification is called a space lattice. Eventually all of the metal is changed from the liquid state, in which the atoms are moving freely, to the solid state, in which the atoms are arranged in a definite, orderly pattern. At this point, we say that the metal has completely solidified or frozen.

If crystallization could proceed without any interference, the result would be one large crystal with the external form of the internal space lattice. As a rule, however, the space lattices do not all line up perfectly with each other; this means that the growth of some crystals interferes with the growth of others.

In other words, space lattices that are not oriented in approximately the same way cannot join each other. As a result, the crystallization process usually results in the growth of many small crystals rather than one large one. In any given piece of solid metal, the size of the crystals will vary. The larger ones are the result of the combination of a great many space lattices that happened to line up in such a way that they could join each other.

Because the crystals interfere with each other as they grow, a piece of metal in cross section may show very few characteristic crystal shapes. Note, however, that the metal is still considered crystalline even if the crystalline forms are distorted. The crystals are there, but they are not usually perfect in shape.

When a metal crystallizes in such a way that the crystals are not perfectly formed and therefore do not have the typical shape of the space lattice, it is customary to call each visible unit a grain rather than a crystal. The areas between adjacent grains are shown as grain boundaries. The grain boundary material has somewhat different properties than the actual grains or crystals; this is partly because the space lattices are distorted at the grain boundaries and partly because the process of crystallization tends to push impurities out of the crystals and into the grain boundaries.

The term grain structure refers to the crystalline structure of the metal, often with particular reference to the shape and size of the grains. Figure 6-6 illustrates several types of gram structure, as seen under a microscope. The size of the grains depends upon a number of factors, including the nature of the metal, the temperature to which it is heated, the length of time it is held at a specified temperature, and the rate at which it is cooled from a liquid to the solid state. In general, the quicker a metal solidifies, the smaller the grain will be. The size of grain structure desired for any particular application depends upon the purpose for which the metal is to be used.

In alloys, the internal structure may be in the form of crystals of pure metals, solid solutions, intermetallic compounds, mechanical mixtures, or some combination of these structures.

In a solid solution, the elements are completely dissolved in each other, with the atoms of each element fitting into and forming part of the space lattice of the other element. Figure 6-7 illustrates two

GLOBULAR
(Spheroidized Steel)

LAMELLAR
(Pearlitic Steel)

ACICULAR
(Martensitic Steel)

DENDRITIC
(Cast Cartridge Brass)

EQUIAXED
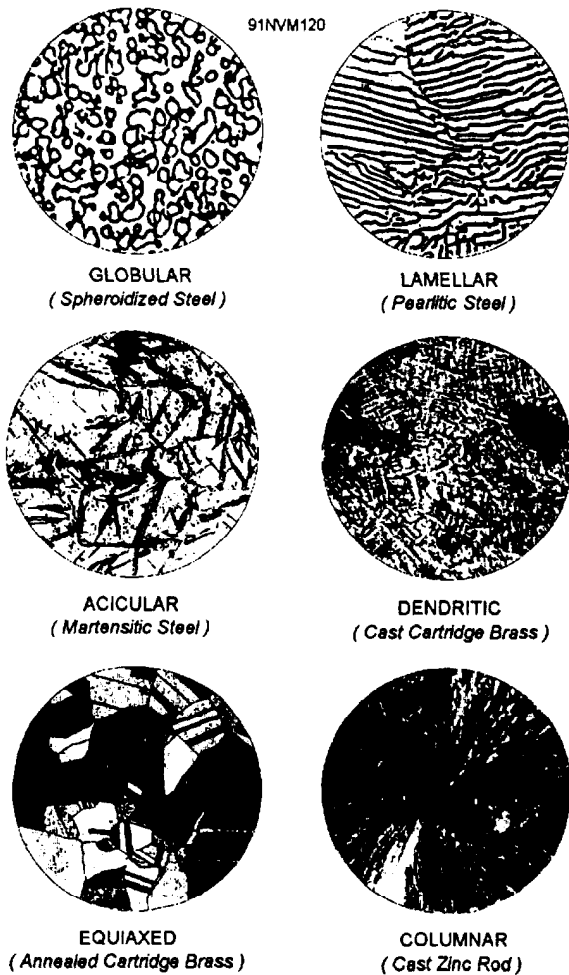(Annealed Cartridge Brass)

COLUMNAR
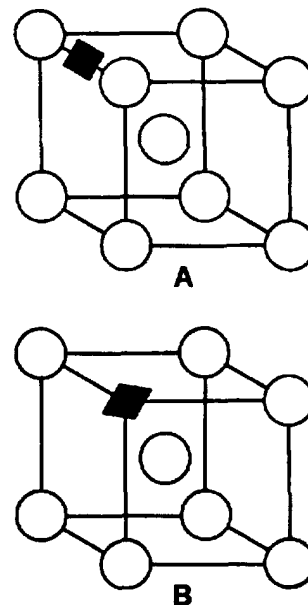(Cast Zinc Rod)

Figure 6-6.—Grain structure in metals.

Figure 6-7.—Space lattices of two forms of solid solution. A. Atoms of one element fit between atoms of another element. B. Atoms of one element replace atoms of another element.

6-5

ways in which solid solutions may exist. The atoms of one element may fit into the spaces between the atoms of another element, as indicated in view A; or the atoms of one element may replace the atoms of another element in the space lattice, as indicated in view B.

A solid solution in a metal is similar to many solutions you are familiar with; for example, water dissolves salt. The result is a wet salty liquid. The taste of the salt and the wetness of the water have not changed. As you see, there has been no change of individual properties. However, you cannot see or distinguish which is water or which is salt. The loss of individual identity is apparent. An example of a familiar solid solution is Monel metal. You know from experience that Monel is tough, and yet, soft and plastic; the toughness of nickel and the plasticity of copper have been combined in the form of a metallic solid solution.

The individual elements lose their identity in a solid solution. A polished cross section of a material that consisted of only one solid solution would show all grains to be of the same nominal composition.

Ferrite and austenite are two solid solutions that are important constituents of steel. Ferrite is the name given to a solid solution of alpha iron and carbon. *Austenite* is the term for a solid solution of gamma iron and carbon. Carbon is only slightly soluble in alpha iron but is quite soluble in gamma iron. Alpha iron at room temperature can hold only about 0.007 percent carbon in solid solution. At a temperature of 2065°F. gamma iron can hold up to about 1.7 percent carbon in solid solution.

INTERMETALLIC COMPOUNDS are compounds formed between a metal and some other substance such as carbon or sulfur. There are many ordinary compounds that we are familiar with in everyday life; common table salt is one. The two poisonous elements, sodium and chlorine, when combined, form sodium chloride or common table salt. Salt does not resemble either sodium or chlorine, either by identity or properties. When the two elements are combined chemically, a new and different substance is created. Under certain conditions, intermetallic compounds form and a new substance with new properties is created in very much the same manner, but on a more complicated basis. Perhaps the most important thing to remember about the intermetallic compounds is the loss of identity and the change in properties. The heat treater quite often utilizes the change in properties offered by compound formations in metals.

One intermetallic compound of great importance in ferrous alloys is known as IRON CARBON or CEMENTITE. This is an extremely hard and brittle compound that is formed by the combination of iron (a metal) and carbon (a metalloid). The formula for iron carbide or cementite is Fe_3C. This formula shows that three atoms of iron combine with one atom of carbon to produce iron carbide, or cementite.

The structure of an alloy is described as being a MECHANICAL MIXTURE when two or more structural forms are mixed together but are still separately distinguishable. A mechanical mixture of an alloy is comparable, though on a smaller scale, to the mixture of sand and gravel that may be seen in concrete.

One of the most important mechanical mixtures that occurs in many steels is known as PEARLITE. Pearlite, so called because it has a pearly luster when seen under a microscope, is an intimate mechanical mixture of ferrite and cementite in alternate plates or layers. Ferrite is a solid solution, and cementite or iron carbide is an intermetallic compound; in pearlite the two are closely mixed to form a characteristic layered structure.

Pearlite is formed when steel that contains just about 0.85 percent carbon is heated to a certain temperature and then cooled slowly. When the entire structure of the alloy is in the form of pearlite, this composition of plain carbon steel (0.85 percent carbon) is often referred to as the eutectoid composition, and the completely pearlitic structure is called the EUTECTOID or the EUTECTOID STRUCTURE.

The internal structure of an alloy may show various combinations of pure metals, solid solutions, intermetallic compounds, and mechanical mixtures. Many of the combinations that are important in steels and other alloys are the result of controlled heating and cooling of the alloy; in other words, they are the result of heat treatment. Figure 6-8 shows, very much enlarged, a typical combination that occurs when plain carbon steel containing less than 0.85 percent carbon is heated to a certain temperature and then cooled slowly. As may be seen, this combination consists of the solid solution ferrite and the mechanical mixture pearlite, each in crystal form, distributed throughout the alloy. The relative proportions of ferrite and pearlite in this combination depend largely upon the carbon content of the alloy.

This combination contains no free crystals of ferrite; instead, it consists of crystals of pearlite surrounded by cementite at the grain boundaries.

PROPERTIES OF METAL

A PHYSICAL PROPERTY is a characteristic of a metal that may be observed or measured. The physical properties of steel are affected by the following:

● Carbon content

● Impurities

● Addition of various alloying metals

● Heat treatment

The particular properties that we require of any metal or alloy depend upon the use we will make of the material. For example, an anchor chain must have the property of toughness; a boiler tube must have high tensile strength, the ability to conduct heat, and the ability to resist deformation or creep at high temperatures; an electric wire must be able to conduct electricity; a knife blade must have the property of hardness; a spring must be elastic; a saltwater piping system must resist corrosion; and a piece of metal that is to be drawn out into a wire must possess the property known as ductility. The following sections deal with some important properties of metals and alloys.
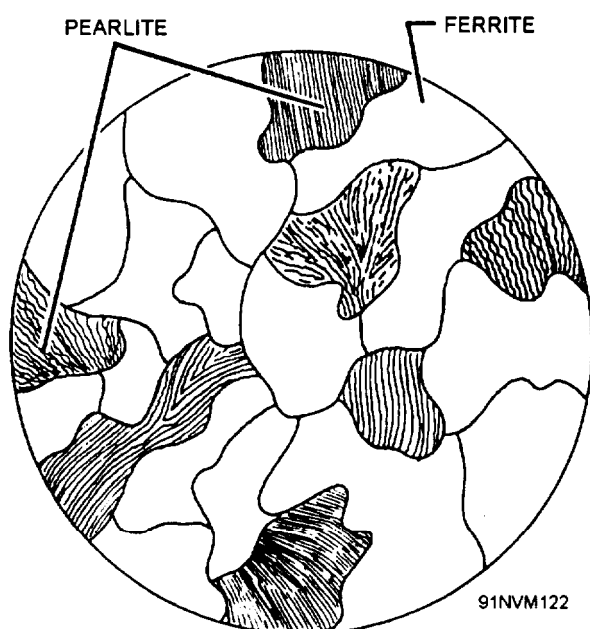

Figure 6-8.—Typical structure of steel containing less than 0.85 percent carbon.

ELASTICITY

As previously noted, a deformation or change of shape (strain) occurs when a material is subjected to external forces that cause stresses in the material. The ability of a material to return to its original size and shape after strain is the property known as elasticity.

All materials are elastic to some extent. It may surprise you to learn that a piece of steel is more elastic than a rubber band. The rubber band stretches more than the steel since it is more easily strained, but the steel returns more nearly to its original shape and size and is, therefore, more truly elastic. Glass is also more elastic than rubber.

The greatest stress that a material is capable of withstanding without taking a permanent set (that is without becoming permanently deformed) is known as the ELASTIC LIMIT. Below the elastic limit, the amount of strain is directly proportional to the amount of stress and, therefore, to the amount of externally applied force. Above the elastic limit, however, the amount of deformation that results from an increase in load is way out of proportion to the increase in load.

Strain may be axial, angular, or both, depending upon the nature of the applied load and the stresses that are developed within the material to withstand the applied load. When the elastic limit is exceeded through the application of an axial load, the material will be permanently deformed either by ELONGATION or by COMPRESSION. When the applied load is not axial (as in shear and torsion), the resulting strain is angular and, if permanent deformation results, the deformation is also angular.

As noted before, the amount of strain is proportional to the amount of stress up to (or almost up to) the elastic limit. The ratio of stress to strain is, therefore, a constant for each material. This constant, which is called the MODULUS OF ELASTICITY, is obtained by dividing the stress by the strain, which is the elongation caused by that stress. For example, suppose that a certain material is so loaded that the internal stress developed in tension is 30,000 psi and that with this stress the material elongates or is strained 0.0015 inch per inch. The modulus of elasticity (E) of this material is

$$E = \frac{\text{Stress (psi)}}{\text{Elongation (inch per inch)}}$$

$$= \frac{30{,}000 \text{ p}si}{0.0015 \text{ inch per inch}}$$

$$= 20{,}000{,}000 \text{ p}si$$

The modulus of elasticity is frequently used to determine the amount of elongation that will occur when a given stress is developed in the material. For this purpose, you divide the stress by the modulus of elasticity to obtain the elongation (inch per inch) that will occur.

Closely related to the elastic limit of a material is the YIELD POINT. The yield point is the stress at which deformation of the material first increases markedly without any increase in the applied load. The yield point is always somewhat above the elastic limit. When the stresses developed in a material are greater than the yield point (or, as it is sometimes called, the yield strength), the material is permanently deformed.

STRENGTH

Strength is the property that enables a material to resist deformation. ULTIMATE STRENGTH is the maximum stress that a material is capable of withstanding in tension, compression, or shear. The COMPRESSIVE STRENGTH of a metal is a measure of how much squeezing force it can withstand before it fails. The metal to be tested is mounted in a tensile tester, but instead of pulling on the metal, a squeezing (compression) force is applied. TENSILE STRENGTH, or the ultimate strength of a material in tension, is the term most frequently used to describe the strength of a material. Tensile strength is the ability of a metal to resist being pulled apart. This property may be measured on a tensile testing machine, which puts a stretching load on the metal. Figure 6-9 illustrates the types of loads imposed on structures.

Table 6-2 shows how the tensile strength, elongation (explained below), and yield point are affected by the carbon content of steel. As the carbon content increases, the tensile strength and yield point first increase then decrease.

Some materials are equally strong in compression, tension, and shear. However, many materials show marked differences. For example, cured portland cement has an ultimate strength of 2,000 psi in compression, but only 600 psi in tension. Carbon steel has an ultimate strength of 56,000 psi in tension and in compression, but an ultimate strength in shear of only 62,000 psi. In dealing with ultimate strength, therefore, the kind of loading (tension, compression, or shear) should always be stated.

If a material is stressed repeatedly, in a cyclical manner it will probably fail at a loading that is considerably below its ultimate strength in tension, compression, or shear. For example, you can break a thin rod with your hands after it has been bent back and forth several times in the same place, although you could not possibly cause an identical rod to fail in tension, compression, or shear merely from force applied by hand. This tendency of a material to fail after repeated stressing at the same point is known as FATIGUE.

METAL FATIGUE

Metal fatigue is the tendency for a metal to break under the action of repeated cyclic stresses. Fatigue may occur for values of cyclic stress considerably less than the ultimate tensile strength of the material. This phenomenon applies to certain fractures in metals that are caused by repeated stresses of a low enough value that a single application of the stress apparently does nothing detrimental to the structure. When enough of these seemingly harmless stresses are applied in a cyclic manner, however, they bring about a small
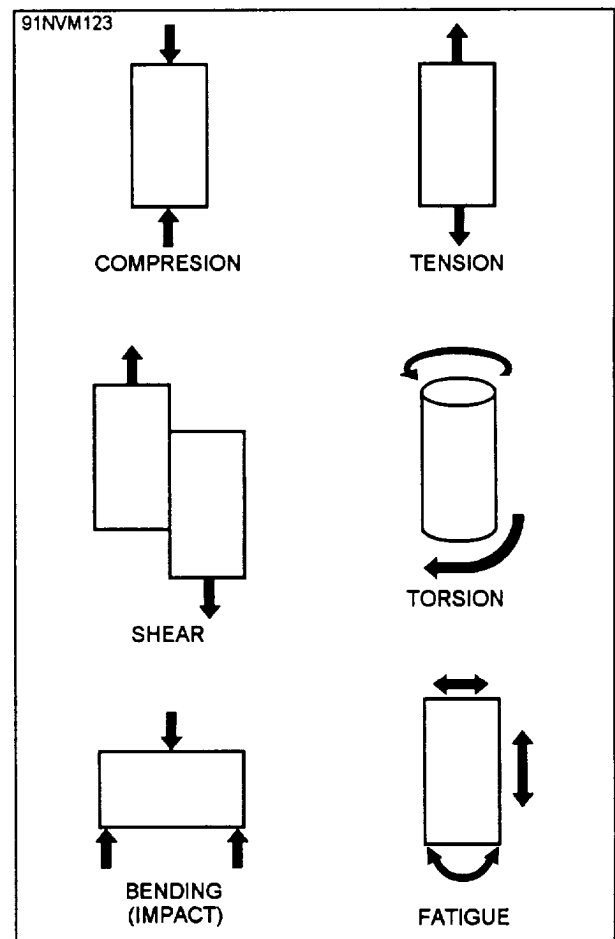
Figure 6-9.—Types of stresses or loads imposed on structures: compression, tension, shear, torsion, bending, and fatigue.

Table 6-2.—Approximate Physical Property Changes of Carbon Steel as the Carbon Content Changes

SAE AISI No.	Carbon Content in Percentages	Tensile Strength Lbs/sq. in	Yield Point Lbs/sq. in.	Elongation in Percentages
1006	.06	43,000	24,000	30
1010	-10	47,000	26,000	28
1020	.20	55,000	30,000	25
1030	.30	68,000	37,500	20
1040	.40	76,000	42,000	18
1050	.50	90,000	49,500	15
1060	.60	98,000	54,000	12
1070	.70	102,000	56,000	12
1080	.80	112,000	56,000	12
1090	.90	122,000	67,000	10
1095	.95	120,000	66,000	10

crack that grows with continued loadings until complete fracture takes place.

Since the small cracks may not be noticed, the metal may fracture with a suddenness that can be dangerous, as in fast-moving vehicles or high-speed machinery. Special inspection techniques have been developed to spot small cracks before the material fails. Fatigue failures are due to the repeated application of tensile stresses or shear stresses, which tend to pull the material apart. However, a cycle that consists of alternating equal stresses in tension and compression, called a fully reversed cycle, is usually used to obtain the endurance limits of a particular material.

HARDNESS

The property of hardness has been defined as the ability of a material to resist penetration. Because there are several methods of measuring hardness, the hardness of a material is always specified in terms of the particular test that has been used to measure this property.

To get a simple idea of the property of hardness, consider lead and steel. You can scratch lead with a pointed wooden stick, but you cannot scratch steel with such a stick. Steel is harder than lead.

TOUGHNESS

Toughness is the property that enables a material to withstand shock, to endure tensile stresses, and to be deformed without breaking. Another way of expressing this is to say that a tough material is one that can absorb a lot of energy before breaking. Toughness does not exist in metals that do not have high tensile strength; however, metals that are both strong and hard tend to have less toughness than metals that are softer and have less tensile strength.

Toughness is definitely related to the property of plasticity; materials must be plastic in order to be tough.

PLASTICITY

Materials that can withstand extensive permanent deformation without breaking or rupturing are said to be highly plastic. Note the use of the word *permanent* in this statement; the term *plastic deformation* is used to indicate a PERMANENT change of shape. Modeling clay is an example of a highly plastic material since it can be deformed extensively and permanently without rupturing. Clay could scarcely be called tough, however, even though it is highly plastic.

Plasticity is in some ways the opposite of brittleness and in other ways the opposite of elasticity. A material that is brittle will break without showing deformation. Such a material is not very plastic. A material that is highly elastic will return to its original shape after strain; consequently, such a material does not show a high degree of plasticity (below the elastic limit for the substance). Most metals are elastic, rather than plastic, up to the elastic limit; above the elastic limit, they tend to have the property of plasticity.

Plasticity, like many other properties, is relative. To some degree, all substances are plastic. Even glass,

which is usually considered to be a nonplastic material, is plastic if an external force is applied to it very slowly. If you want to demonstrate this to yourself, take a sheet of glass and lay it in a horizontal position in such a way that it is supported only at the ends. Then put a weight in the middle of the glass. After several days (or possibly weeks, depending upon the kind of glass you use), you will be able to observe a visible deformation of the glass.

The substance known as "Silly Putty" is an even better example of the relative nature of the property of plasticity. When you slowly press or mold "Silly Putty," it is more plastic than chewing gum; throw it against the floor and it may either bounce like a rubber ball or break into pieces; hit it sharply with a hammer, and it will shatter almost like glass.

Before these properties are studied in detail, the welder should have an understanding of the effect of carbon on the properties of steel and a knowledge of alloys in general.

DUCTILITY AND MALLEABILITY

The properties known as ductility and malleability are special cases of plasticity. Ductility is the property that makes it possible for a material to be drawn out into a thin wire or, in other words, it is the property that enables the material to withstand extensive permanent deformation from TENSION. Ductility is the ability of a metal to be stretched. A very ductile metal such as copper or aluminum may be pulled through dies to form wire. Malleability is the property that makes it possible for a material to be stamped, hammered, or rolled into thin sheets; a malleable material is one that can withstand extensive permanent deformation from COMPRESSION.

Most metals that exhibit one of these properties also exhibit the other. However, this is not always true. Lead, for example, is very malleable (it can be permanently deformed in compression without breaking), but it is not ductile (it cannot be permanently deformed in tension to any great extent).

CREEP RESISTANCE

The term *creep* describes a special kind of plastic deformation that occurs very slowly at high temperatures when the material is under a constant stress. It is interesting to note that this stress may be considerably less than the yield point of the material at room temperature. Because creep occurs very slowly at or below room temperature (so slowly, in fact, that years are required to complete a single creep test), the importance of this type of plastic deformation has not been recognized until fairly recent. Creep-resisting steel is now used in most modem naval ships for high-temperature piping.

BRITTLENESS

Brittleness is the opposite of ductility. A brittle metal will fracture if it is bent or struck a sharp blow. A brittle material is one that fractures before exhibiting any noticeable permanent deformation. Most cast iron is very brittle.

CORROSION RESISTANCE

Corrosion resistance is the property that enables a material to resist entering into chemical combination with other substances. A high degree of corrosion resistance would be very desirable in all metals used aboard ship. Most metals are easily corroded, however, as shown by the fact that pure metals occur only rarely in nature.

The presence of impurities, or the presence of alloying elements, may greatly alter the corrosion resistance of a metal. For example, the zinc that is known as "commercially pure" contains a small amount of impurities; this grade of zinc corrodes about 10,000 times as fast as zinc that is chemically pure. On the other hand, many alloys have been developed for the particular purpose of increasing the corrosion resistance of the material. For example, pure iron would be entirely unsuitable for use in boilers because it has very poor resistance to corrosion, particularly at high temperatures; yet alloys composed primarily of iron are used successfully for this service.

WELDABILITY AND MACHINABILITY

Although not strictly properties, in the sense of the other properties we have discussed, weldability and machinability are important practical considerations in the fabrication or repair of any metal part. Weldability refers to the relative ease with which a metal may be welded. Machinability describes the ease with which a metal may be turned, planed, milled, or otherwise shaped in the machine shop. Some metals are not easily machined because they are too hard. Some soft metals are not easily machined because they are too tough. Both weldability and machinability are really based upon the combination of other properties

of the material, rather than being properties themselves.

TYPES OF METAL

Metals are divided into two major fields: ferrous metals and nonferrous metals. Ferrous metals are those that are composed primarily of iron. Nonferrous metals are those that are composed primarily of some element or elements other than iron. Nonferrous metals or alloys sometimes contain a small amount of iron as an alloying element or impurity.

FERROUS METALS

Ferrous metals include all forms of iron and steel. Ferrous metals are widely used in the construction of ships.

Iron

Commercially pure iron is known as INGOT IRON. This iron is 99.85 percent iron; carbon, manganese, phosphorous, sulfur, and a trace of silicon make up the remainder. The chemical composition of this iron is very similar to the chemical composition of the lowest carbon steel.

WROUGHT IRON was used extensively for construction and even for machinery before steels came into use. Wrought iron is a mixture of very pure iron and silica slag. The slag gives wrought iron some of its desirable properties—corrosion resistance, weldability, and ductility, among others. Wrought iron is still used for some piping systems on auxiliary ships.

CAST IRON is produced by resmelting a charge of pig iron and scrap iron and removing some of the impurities from the molten metal by using various fluxing agents. There are many grades of cast iron, rated as to strength and hardness. The four major kinds of cast iron are white cast iron, gray cast iron, malleable cast iron, and nodular cast iron. With the exception of similarity between nodular and malleable cast iron, there are considerable differences in the properties of the various kinds of cast iron. The form in which the carbon exists (graphite or cementite) and the mode of its distribution are chiefly responsible for the differences in properties.

White cast iron essentially consists of an alloy of iron, carbon, and silicon. It is known chiefly for its good wear resistance and as the starting point for producing malleable cast iron. White cast iron derived its name from the bright silvery appearance it has when fractured. White cast iron is hard, brittle, wear resistant, and unmachinable, largely because the carbon it contains is present as cementite.

Gray cast iron always contains iron, carbon, and silicon, and generally contains more carbon and silicon than white cast iron. Carbon is always present in the form of graphite flakes. In addition, gray cast iron often contains appreciable amounts of nickel and other alloying elements. Gray cast iron is of three varieties: common, high strength, and alloy. All three are machinable and have good damping capacity (ability to absorb and dampen vibrations). The common gray cast irons are quite soft; the others are somewhat stronger, particularly the alloy gray cast iron. All three are brittle because the carbon they contain is largely present in graphite flakes, which act as severe stress raisers. Whether a cast iron is gray or white depends upon the cooling rate and carbon, silicon, and nickel content.

Malleable cast iron is made by heating white castings to 1700°F for about 50 hours, followed by slow cooling to room temperature. The castings are packed in a neutral slag or scale during heating and cooling. During the heating period, the cementite in the structure tends to decompose into ferrite plus temper carbon. Malleable cast iron is strong, machinable, and ductile. The mechanical properties of malleable cast iron compare favorably with those of low-carbon steels. Malleable cast iron is a great deal more ductile than either white or gray cast iron.

Nodular cast iron is produced in the same way as gray cast iron, but with much closer control of composition and with the aid of inoculating agents. The molten iron is inoculated with an alloy that will produce spherical graphite rather than flake graphite. Nodular cast iron possesses the good machinability, damping capacity, and castability of gray cast iron. Its strength is comparable to alloy gray cast irons and cast carbon steel. The ductility of nodular cast iron is about half that of cast steel, far better than gray cast iron.

Steel

Steels and other metals are classified on the basis of the method of manufacture, method of shaping, method of heat treatment, properties, intended use, and chemical composition. In addition, certain steels and other metals are often referred to by trade names.

When classified according to the method of manufacture, steels are known as (I) basic, open hearth; (2) basic, electric; (3) acid, Bessemer; (4) acid, electric; (5) acid, open hearth; or (6) basic, oxygen furnace. The method of manufacture has a lot to do with the properties of the finished steel, so these distinctions are important to metallurgists and to design engineers. Since the method of manufacture is not usually important to the HT, these processes will not be discussed in this training manual.

When classified according to the method of shaping, steels are often referred to as cold rolled steel, forged steel, drawn steel, and cast steel.

Classifying steels according to the method or methods of heat treatment leads to such terms as *annealed steel,* and *casehardened steel.*

Classifying steels according to properties gives us such classes as corrosion-resisting steels (CRES); heat-resisting steels; low-expansion steels; free-machining or free-cutting steels; casehardening steels; high tensile steels (HTS); and special treatment steel (STS).

Probably the most reasonable way to classify steels is by their chemical composition. Steels that derive their properties primarily from the presence of carbon are referred to merely as "steels" or sometimes as "plain carbon steels." Steels that derive their properties primarily from the presence of some alloying element other than carbon are referred to as "alloys" or "alloy steels." Note, however, that plain carbon steels always contain some carbon. Note, also, that the use of the word *alloy* should not really be limited to mean an alloy steel, since there are many alloys that contain no iron at all and are, therefore, not steels.

Plain Carbon Steel

Plain carbon steels vary in carbon content from about 0.05 percent to as much as 1.70 percent carbon. The properties of the steel depend upon the amount of carbon present and the particular way in which the iron and the carbon combine. The plain carbon steels are known (in increasing order of the amount of carbon present) as mild steel, low-carbon steel, medium-carbon steel, high-carbon steel, and very-high-carbon steel.

Alloy Steel

An alloy metal may be defined as an intimate mixture of two or more elements. Any ferrous or nonferrous metal may be alloyed to form an alloy metal with new and desirable characteristics.

A simple alloy consists of two metals in any proportion. An example of a simple alloy is the combination of tin and lead, which is called solder. The melting temperature of the lead is 621°F (327°C). Tin has a melting temperature of 450°F (232°C). However, as the two metals are mixed, any combination of the two results in a lower melting temperature than 621°F (327°C). At a certain proportion of the metals, the lowest melting temperature is reached. This point is called the EUTECTIC POINT.

Steel is a combination of iron and controlled amounts of carbon. Alloy steels are created by adding other elements to plain carbon steel. Alloy steels are identified by the name of the alloying element or elements, usually without reference to the carbon that is present. Alloy steels are further identified as low-alloy steels or high-alloy steels, depending upon the amount of alloying material that is present. Some elements that are alloyed with carbon steel and the qualities imparted to steel by each are as follows:

CHROMIUM—Increases resistance to corrosion and improves hardness, toughness, wear resistance, strength, and the responsiveness to heat treatment.

MANGANESE—Increases strength and responsiveness to heat treatment.

MOLYBDENUM—Increases toughness and improves the strength of steel at higher temperatures.

NICKEL—Increases strength, ductility, and toughness.

TUNGSTEN—Produces dense, fine grains; helps steel to retain its hardness and strength at high temperatures.

SILICON—Improves the electrical quality of the steel.

VANADIUM—Retards grain growth and improves toughness.

NONFERROUS METALS

Although ferrous metals are used aboard ship in greater quantities than the nonferrous metals, the nonferrous metals are nevertheless of great

importance. Copper, zinc, lead, and a large number of nonferrous alloys are required in the construction and maintenance of naval ships. Some of the more popular nonferrous metals a welder encounters are copper, brass, zinc, bronze, lead, and aluminum.

The various welding processes now make it possible to satisfactorily weld practically all nonferrous metals.

Copper

Copper is one of the most important nonferrous metals used in the construction of a ship. It is used in the form of sheets, tubing, wires, and in copper alloys such as brass and bronze. It is used to give a protective coating to other metals, and to fabricate many special parts.

The properties of copper make it extremely useful for many applications. It is easy to work; it is ductile, malleable, tough, strong, resistant to wear, and machinable. Copper is highly resistant to saltwater corrosion and is an excellent conductor of both heat and electricity. Copper seams are usually joined by riveting, brazing, or soldering.

ZINC

Zinc is used as a protective coating (galvanizing) on steel and iron. Zinc is also used in the form of zinc chloride for soldering fluxes and as an alloying element in some brass and bronze.

High-purity zinc, in the form of sheets, rods, or special shapes, is used to protect hulls, hull fittings, and many types of machinery from the effects of galvanic action.

Lead

Lead is probably the heaviest metal that you will ever use on board ship. Lead weighs about 700 pounds per cubic foot, but in spite of its weight, it is soft and malleable. Lead is commonly supplied in sheet form, rolled up on a rod. To use it, you merely unroll it and cut off as much as you need.

Because of its softness, lead is often used as a backing material for punching and hammering operations. Sheet lead is used to line sinks and to protect bench tops that are exposed to acids. Lead is also used as a radiation shield.

Tin

Tin is seldom used aboard ship in its pure state, but it has many important uses as an alloying element. Tin and lead are used together to make soft solders; tin and copper are used together to make bronze. Tin and tin-based alloys have, in general, a high resistance to corrosion.

Brass

True brass is an alloy of copper and zinc. Additional elements—aluminum, lead, tin, iron, manganese, or phosphorous—may be added to give the alloy specific properties. Rolled naval brass (also known as Tobin bronze) is about 60 percent copper, 39 percent zinc, and 0.75 percent tin. This type of brass is highly resistant to corrosion.

Brass sheets and strips are available in grades known as soft, 1/4 hard, 1/2 hard, full hard, and spring. Hardness is imparted to the brass by the process of cold rolling. Most grades of brass can be made softer by annealing the metal at a temperature of 800° to 1200°F.

Bronze

A bronze made of 84 percent copper and 16 percent tin was the best metal available for tools, weapons, and so on, before techniques were developed for making steel. Many complex bronze alloys, containing additional elements such as zinc, lead, iron, aluminum, silicon, and phosphorous are now available. The name bronze is now applied to any copper-base alloy that looks like bronze; in many cases, there is no longer a real distinction to be made between bronze and brass.

Aluminum and Aluminum Alloys

Aluminum and aluminum alloys are widely used because they are lightweight, easily worked, and strong in relation to their weight. There are now so many different types of aluminum alloys in use that a special numbering system has been adopted for these alloys.

IDENTIFICATION OF METALS

Material is used daily and, normally, there will be some material left over. Quite often the means of marking the material was cut off, or worn off, leaving

the material to a guessing game as to what type of material it is. Granted, it is best to make out a tag with all the important information as to the type of material, the alloy composition, and possibly the stock number of that material. Even then, tags are subject to being lost. Therefore, let us look at the various ways to identify the material according to surface appearance and identification tests.

IDENTIFICATION BY SURFACE APPEARANCE

It is possible to identify several metals by their surface appearance. Although examination of the surface does not usually give you enough information to classify the metal exactly, it will often give you enough information to allow you to identify the group to which the metal belongs. Even this much identification is helpful since it will limit the number of tests required for further identification.

In trying to identify a piece of metal by its surface appearance, consider both the color and the texture of the surface. Table 6-3 gives the surface colors of some common metals.

IDENTIFICATION TESTS

If the surface appearance of a metal does not give enough information to allow adequate identification, metal identification tests are necessary. A number of such tests are used. Some of these tests are complicated and require equipment that you are not likely to have. Others, however, are relatively simple and quite reliable when performed by a skilled person. The following tests are the most common for shop use:

● Spark test (with the power grinder)

● Oxyacetylene torch test

● Fracture test

Table 6-3.—Surface Colors of Some Common Metals

Metals	Color of unfinished, unbroken surface	Color and structure of newly fractured surface	Color of freshly filed surface
White cast iron	Dull gray	Silvery white; crystalline	Silvery white
Gray cast iron	Dull gray	Dark silvery; crystalline	Light silvery gray
Malleable iron	Dull gray	Dark gray; finely crystalline	Light silvery gray
Wrought iron	Light gray	Bright gray	Light silvery gray
Low carbon and cast steel	Dark gray	Bright gray	Bright silvery gray
High carbon steel	Dark gray	Light gray	Bright silvery gray
Stainless steel	Dark gray	Medium gray	Bright silvery gray
Copper	Reddish brown to green	Bright red	Bright copper color
Brass and bronze	Reddish yellow, yellow-green, or brown	Red to yellow	Reddish yellow to yellowish white
Aluminum	Light gray	White; finely crystalline	White
Monel metal	Dark gray	Light gray	Light gray
Nickel	Dark gray	Off white	Bright silvery white
Lead	White to gray	Light gray; crystalline	White
Copper-Nickel (70-30)	Gray	Light gray	Bright silvery white

- Color test

- Density or specific gravity test

- Ring or sound of the metal upon impacting with some other metal

- Magnetic test

- Chip test

Spark Test

The spark test is made by holding a sample of the material against a power grinder. The sparks given off, or the lack of sparks, assist in identifying the metal. The length of the spark stream, its color, and the type of sparks are the features for which you should look.

There are four fundamental spark forms produced by holding a sample of metal against a power grinder. (See fig. 6-10.) View A shows shafts, buds, breaks, and arrows. The arrow or spearhead is characteristic of molybdenum, an alloying element in steel. When swelling or buds are present in the spark line, nickel is also present as an alloying element with molybdenum. View B shows shafts and sprigs, or sparklets, which indicate a high carbon content. View C shows shafts, forks, and sprigs that indicate a medium carbon content. View D shows shafts and forks that indicate a low carbon content.

The greater the amount of carbon present in the steel, the greater the intensity of bursting that will take place in the spark stream. To understand the cause of the bursts, remember that while the spark is glowing and in contact with the oxygen of the air, the carbon present in the particle is burned to carbon dioxide. As the solid carbon combines with oxygen to form carbon dioxide in the gaseous state, the increase in volume builds up a pressure that is relieved by an explosion of the particle. An examination of the small steel particles under a microscope when they are cold reveals a hollow sphere with one end completely blown away.

Steels having the same carbon content but differing alloying elements are not always easily identified because alloying elements affect the carrier lines, the bursts, or the forms of characteristic bursts in the spark picture. The effect of the alloying element may retard or accelerate the carbon spark or make the carrier line lighter or darker in color. Molybdenum, for example, appears as a detached, orange-colored, spearhead on the end of the carrier line. Nickel seems
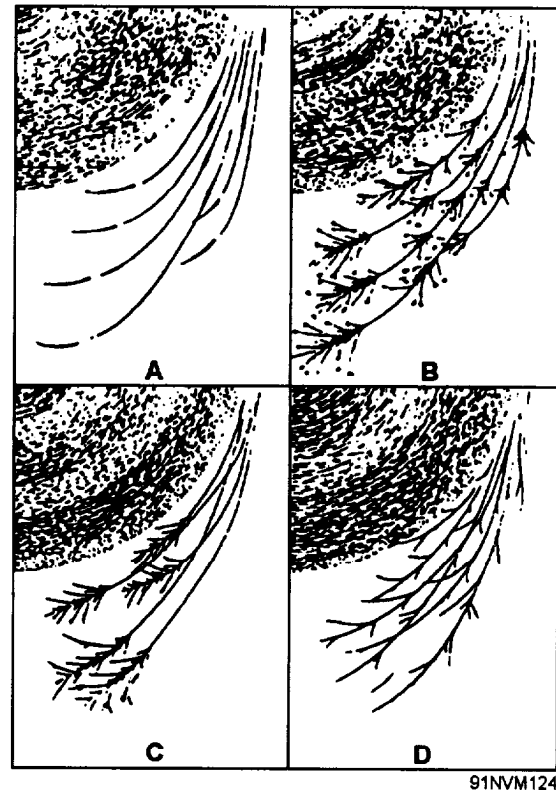

Figure 6-10.—Fundamental spark forms.

to suppress the effect of the carbon burst. However, the nickel spark can be identified by tiny blocks of brilliant white light. Silicon suppresses the carbon burst even more than nickel. When silicon is present, the carrier line usually ends abruptly in a white flash of light.

To make the spark test, hold the piece of metal against the wheel in such a manner as to throw the spark stream about 12 inches at a right angle to your line of vision. You will need to spend a little time to discover at just what pressure you must hold the sample to get a stream of this length without reducing the speed of the grinder. It is important that you do not press too hard because the pressure will increase the temperature of the spark stream and the burst. It will also give the appearance of a higher carbon content than that of the metal actually being tested. After practicing to get the feel of correct pressure on the wheel until you're sure you have it, select a couple of samples of metal with widely varying characteristics; for example, low-carbon steel and high-carbon steel. Hold first one then the other against the wheel, always being careful to strike the same portion of the wheel with each piece. With your eyes focused at a point about one-third of the distance from the tail end of the stream of sparks, watch only those sparks that cross the line of vision. You will find

that after a little while, you will form a mental image of the individual spark. After you can fix the spark image in mind, you are ready to examine the whole spark picture.

Notice that the spark stream is long (about 70 inches normally) in low-carbon steel, and that the volume is moderately large; while in high-carbon steel, the stream is shorter (about 55 inches) and larger in volume. The few sparklers that may occur at any place in low-carbon steel are forked, while in high-carbon steel the sparklers are small and repeating, and some of the shafts may be forked. Both will produce a white spark stream.

White cast iron produces a spark stream approximately 20 inches in length (see fig. 6-11). The volume of sparks is small with many small and repeating sparklers. The color of the spark stream close to the wheel is red, while the outer end of the stream is straw colored.

Gray cast iron produces a stream of sparks about 25 inches in length. It is small in volume with fewer sparklers than white cast iron. The sparklers are small and repeating. Part of the stream near the grinding wheel is red, and the outer end of the stream is straw colored.

The malleable iron spark test will produce a spark stream about 30 inches in length. It is of a moderate volume with many small, repeating sparklers toward the end of the stream. The entire stream is straw colored.

The wrought iron spark test produces a spark stream about 65 inches in length. The stream is of large volume with few sparklers. The sparklers show up toward the end of the stream and are forked. The stream next to the grinding wheel is straw colored, while the outer end of the stream is a bright red.

Stainless steel produces a spark stream approximately 50 inches in length, of moderate volume, with few sparklers. The sparklers are forked. The stream next to the wheel is straw colored. The sparks form wavy streaks with no sparklers.

Monel metal forms a spark stream almost identical to that of nickel and must be identified by other means. Copper, brass, bronze, and lead form no sparks on the grinding wheel, but they are easily identified by other means, such as color, appearance, and chip tests.

You will find the spark tests easy and convenient to make. They require no special equipment and are adaptable to most any situation. Here again, experience is the best teacher.

It is good practice to compare the sparks of an unknown metal with those of a known metal. This permits an additional check on the tester's conclusion and also can distinguish between different metals that
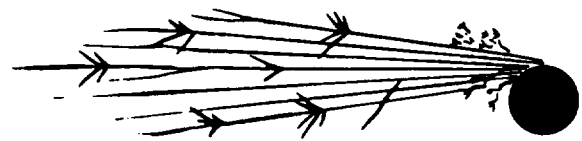
A SPARKS PRODUCED FROM LOW-CARBON CAST STEEL

B SPARKS PRODUCED FROM HIGH-CARBON STEEL

C SPARKS PRODUCED FROM GRAY CAST IRON

D SPARKS PRODUCED FROM MONEL AND NICKEL

E SPARKS PRODUCED FROM STAINLESS STEEL

F SPARKS PRODUCED FROM WROUGH IRON

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Figure 6-11.—spark pictures formed by common metals.

have similar spark patterns. It is the practice in many metal shops to maintain a cabinet of commonly used metals, positively identified as to grade, for comparison with unknown samples.

Proper lighting conditions are essential for good spark testing practice. Testing should not be done in strong direct lighting. A dark background for the spark

pattern should be used. Heavy drafts of air against the spark pattern should be avoided as the air can change the tail sparks. Such a change will lead to incorrect identification.

Oxyacetylene Torch Test

Even if you know the physical composition and the chemical composition of a metal, you must also know whether the metal has good welding properties. For example, some cold rolled sheet steels may show very good physical and chemical properties. However, during some part of the manufacturing process, impurities may have been added to it or certain work may have been done to the metal affecting its properties. The metal may not melt and fuse readily. The final weld may be unsatisfactory. The usual cause of this condition is that there are impurities imbedded in the metal. The impurities are usually slag and roller dirt or excessive sulphur and phosphorus. For these reasons, a welder should subject steel to the torch test.

Metals may sometimes be identified by their characteristic reactions to being heated with an oxyacetylene welding torch. Identifying factors include the rate of melting, the appearance of the molten slag, and the color changes (if any) that occur during the heating. Table 6-4 indicates the reactions of various metals to the torch test.

Table 6-4.—Identification of Metals by Oxyacetylene Torch Test

Metals	Reactions When Heated By Oxyacetylene Torch
White cast iron	Metal becomes dull red before melting. Melts at moderate rate. A medium tough film of slag develops. Molten metal is watery, reddish white in color, and does not show sparks. When flame is removed, depression in surface of metal under flame disappears.
Gray cast iron	Puddle of molten metal is quiet, rather watery, but with heavy, tough film forming on surface. When torch flame is raised, depression in surface of metal disappears instantly. Molten puddle takes time to solidify, and gives off no sparks.
Malleable iron	Metal becomes bright red before melting: melts at moderate rate. A medium tough film of slag develops, but can be broken up. Molten puddle is straw colored, watery, and leaves blowholes when it boils. Center of puddle does not give off sparks, but the bright outside portion does.
Wrought iron	Metal becomes bright red before it melts. Melting occurs quietly and rapidly, without sparking. There is a characteristic slag coating, greasy or oily in appearance, with white lines. The straw-colored molten puddle is not viscous, is usually quiet but may have a tendency to spark; is easily broken up.
Low-carbon and cast steel	Melts quickly under the torch, becoming bright red before it melts. Molten puddle is liquid, straw colored, gives off sparks when melted, and solidifies almost instantly. Slag is similar to the molten metal and is quiet.
High-carbon steel	Metal becomes bright red before melting, melts rapidly. Melting surface has cellular appearance, and is brighter than molten metal of low-carbon steel; sparks more freely, and sparks are whiter. Slag is similar to the molten metal and is quiet.
Stainless steels	Reactions vary depending upon the composition.
Copper	Metal has high heat conductivity; therefore, larger flame is required to produce fusion than would be required for same size piece of steel. Copper color may become intense before metal melts; metal melts slowly, and may turn black and then red. There is little slag. Molten puddle shows mirror like surface directly under flame, and tends to bubble. Copper that contains small amounts of other metals melts more easily, solidifies more slowly, than pure copper.
Brass and Bronze	These metals melt very rapidly, becoming noticeably red before melting. True brass gives off white fumes when melting. Bronze flows very freely when melting, and may fume slightly.
Aluminum and aluminum alloys	Melting is very rapid, with no apparent change in color of metal. Molten puddle is same color as unheated metal and is fluid; stiff black scum forms on surface, tends to mix with the metal, and is difficult to remove.
Monel	Melts more slowly than steel, becoming red before melting. Slag is gray scum, quiet and hard to break up. Under the scum, molten puddle is fluid and quiet.
Nickel	Melts slowly (about like Monel), becoming red before melting. Slag is gray scum, quiet and hard to break up. Under the scum, molten puddle is fluid and quiet.
Lead	Melts at very low temperature, with no apparent change in color. Molten metal is white and fluid under a thin coating of dull gray slag. At higher temperature, puddle boils and gives off poisonous fumes.

The actual test consists of melting a puddle in the steel. If the metal is thin, the puddle penetrates through the thickness of the steel until a hole is formed. This puddling should be done with a neutral flame, held at the proper distance from the metal. The puddle should not spark excessively or boil. The puddle should be fluid and should possess good surface tension. The appearance on the edge of the puddle or hole indicates the weldability of the steel. If the metal that was melted has an even, shiny appearance upon solidification, the metal is generally considered as having good welding properties. However, if the molten metal surface is dull or has a colored surface, the steel is unsatisfactory for welding. The steel is also considered unsatisfactory for welding if the surface is rough, perhaps even broken up into small pits or porous spots.

This test is accurate enough for most welding. The test is very easily applied with the equipment on the job. The test determines the one thing that is fundamentally necessary in any welding job, that is, the weldability of the metal. Figure 6-12 shows how this test is conducted. While performing the weldability test of the metal, it is important to note the amount of sparking emitted from the molten metal. A metal that emits few sparks has good welding qualities.
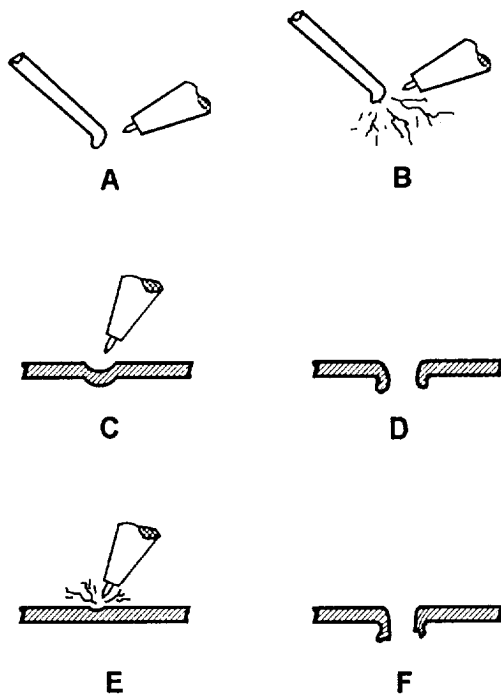
Figure 6-12.—Torch flame test: (A) Good quality filler rod. (B) Poor quality filler rod. (C) and (D) Good quality base metal. (E) and (F) Poor quality base metal.

Chip Test

Another test that must be accompanied by considerable experience is the chip test. To make a chip test, use a sharp cold chisel to remove a small amount of metal from a sample. The ease with which the chipping can be done gives some indication of the kind of metal with which you are working. The size, form, and color of the chips and the appearance of the edges (whether smooth or sawtoothed) give further clues.

In this test, the cutting action of the chisel indicates the structure and heat treatment of the metal. Cast iron, for example, when being chip-tested, breaks off in small particles, whereas a mild steel chip tends to curl and cling to the original piece. Higher-carbon, heat-treated steels cannot be tested this way because of hardness. A rough test between mild carbon steel and chrome-moly steel may be indicated by the relative hardness of the metals while being hacksawed.

You will not be able to identify metals by the chip test method until you have had considerable experience. You should practice with samples of known metals until you have learned how to identify carbon steel, carbon-molybdenum steel, chromium-molybdenum steel, chromium-nickel steel, and other metals. The information given in table 6-5 will help you to recognize some of the more common metals.

Fracture Test

The fracture test is used extensively and consists of breaking a portion of the metal in two. If it is a repair job, the fractured surface may be inspected. The appearance of the surface where the metal is cracked shows the grain structure of the metal. If the grains are large, the metal is ductile and weak. If the grains are small, the metal is usually strong and has better ductility. Small grains are usually preferred. The fracture shows the color of the metal, which is a good means of identifying one metal from another. The test also indicates the type of metal by the ease with which it may be fractured.

Color Test

The color test separates two main divisions of metals. The irons and steels are indicated by their typical gray white color. Nonferrous metals come in two general color classifications of yellow and white.

6-18

Table 6-5.—Identification of Metals by Chip Test

Metals	Chip Characteristics
White cast iron	Chips are small, brittle fragments. Chipped surfaces are not smooth.
Gray cast iron	Chips are about 1/8 inch in length. Metal is not easily chipped, so chips break off and prevent smooth cut.
Malleable iron	Chips are from 1/4 to 3/8 inch in length (larger than chips from cast iron). Metal is tough and hard to chip.
Wrought iron	Chips have smooth edges. Metal is easily cut or chipped, and chip can be made as a continuous strip.
Low-carbon and cast steel	Chips have smooth edges. Metal is easily cut or chipped, and chip can be taken off as a continuous strip.
High-carbon steel	Chips show a fine grain structure. Edges of chips are lighter in color than chips of low-carbon steel. Metal is hard, but can be chipped in a continuous strip.
Copper	Chips are smooth, with sawtooth edges where cut. Metal is easily cut. Chip can be cut as a continuous strip.
Brass and bronze	Chips are smooth, with sawtooth edges. These metals are easily cut, but chips are more brittle than chips of copper. Continuous strip is not easily cut.
Aluminum and aluminum alloys	Chips are smooth, with sawtooth edges. Chip can be cut as a continuous strip.
Monel	Chips have smooth edges. Continuous strip can be cut. Metal chips easily.
Nickel	Chips have smooth edges. Continuous strip can be cut. Metal chips easily.
Lead	Chips of any shape may be obtained because the metal is so soft that it can be cut with a knife.

Copper, brass, and bronze can be rather easily identified by a welder. Aluminum is a white metal. Aluminum alloys, zinc, and the like, are all of somewhat the same silver-gray color although they may vary in shade.

Density Test

Metals may also be differentiated by means of the weight or density test of the specimen. A good example of identification by density or specific gravity is identifying aluminum and lead. Roughly speaking, their colors are somewhat similar, but anyone may readily distinguish between the two metals because of their respective weights. Lead weighs about three times as much as aluminum.

Ring Test

The ring test, or the sound of the metal test, is an easy means of identifying certain metals after some experience with this method. It is used extensively for identifying heat-treated steels from annealed steels. It is also used to detect alloys from the virgin metal. An example is the difference between aluminum and duralumin, an alloy of aluminum and copper (2017-T) (the letter T indicates that the metal is heat treated). The pure aluminum sheet has a duller sound, or ring, than the duralumin, which is somewhat harder and has a more distinct ringing sound.

Magnetic Test

The magnetic test is another method used to aid in the general identification of metals. Frequently, the

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inexperienced person confused aluminum and stainless steels. Remember that ferrous metals, being iron-based alloys, are magnetic whereas nonferrous metals are nonmagnetic.

Nitric Acid Test

The nitric acid test is one of the easiest tests to distinguish between stainless steel, Monel, copper nickel, carbon steels, and various other metals. You need no special training in chemistry to perform this test. However, you must observe the following safety precautions when using or handling acids of any type:

— Never open more than one container of acid at one time.

— Use only glass containers when mixing or stowing acids.

— In mixing, always pour acid slowly into water. NEVER pour water into acid, because an explosion is likely to occur.

— If any acid is spilled, dilute it with plenty of water to weaken it so that it can safely be swabbed away.

— If an acid is spilled on the skin, wash immediately with large quantities of water. Then wash with a solution of borax and water.

— Wear safety goggles. Clear-lens goggles will make it easier to detect the reaction of a metal to an acid test, which may be evidenced by a color change, the formation of a deposit, or the development of a spot.

— Conduct tests in a well-ventilated area.

To perform the nitric acid test, place one or two drops of concentrated (full strength) nitric acid on a metal surface that has been cleaned by grinding or filing. Observe the resulting reaction (if any) for about 2 minutes. Then add three or four drops of water, one drop at a time, and continue observing the reaction. If there is no reaction at all, the test material may be one of the stainless steels.

The reaction that results in a brown-colored liquid indicates a plain carbon steel. A reaction producing a brown to black color indicates a gray cast iron or one of the alloy steels containing as its principal element either chromium, molybdenum, or vanadium. Nickel steel reacts to the nitric acid test by forming a brown to greenish-black liquid, while a steel containing tungsten reacts slowly to form a brown-colored liquid with a yellow sediment.

Instead of the brown-black colors that usually appear when ferrous metals are tested, various shades of green and blue appear as the material dissolves when nonferrous metals and alloys are subjected to the nitric acid test. Except with nickel and Monel, the reaction is vigorous. The reaction of nitric acid on nickel proceeds slowly, developing a pale green color. On Monel, the reaction takes place at about the same rate as on ferrous metals, but the characteristic color of the liquid is greenish-blue. Brass reacts vigorously, with the test material turning to a green color. Tin bronze, aluminum bronze, and copper all react vigorously in the nitric acid test, with the liquid changing to a blue-green color. Aluminum and magnesium alloys, lead, lead-silver, and lead-tin alloys are soluble in nitric acid, but the blue or green color is lacking.

From the information given thus far, it is easy to see that it will require considerable visual skills to identify the many different reactions of metals to nitric acid. As an HT, you will be mostly concerned with the identification of stainless steel, Monel, and carbon steel.

File Hardness Test

Hardness tests are commonly used to determine the ability of a material under test to resist abrasion or penetration by another material. Many methods have evolved for measuring the hardness of metal. The simplest method is the file hardness test. This test cannot be used to make positive identification of metals but can be used to get a general idea of the type of metal being tested and to compare the hardness of various metals on hand. Thus, when identification of metal by other means is not possible, you might use a file to determine the relative hardness of various metals. The results of such a test may enable you to select a metal more suitable for the job being performed.

The file hardness test is simple to perform. The metal being tested may be held by hand and rested on a bench, or held in a vise. Grasp the file, with the index finger extended along the file, and apply the file slowly but firmly to the surface being tested.

If the material is cut by the file with extreme ease and tends to clog the spaces between the file teeth, it is VERY SOFT. If the material offers some resistance to the cutting action of the file and tends to

clog the file teeth, it is SOFT. If the material offers considerable resistance to the file but can be filed by repeated effort, it is HARD and may or may not have been heat treated. If the material can be removed only by extreme effort and in small quantities by the file teeth, it is VERY HARD and has probably been heat treated. If the file slides over the material and the file teeth are dulled, the material is EXTREMELY HARD and has been heat treated.

The file test is not a scientific method. It should not be used when positive identification of metal is necessary or when an accurate measurement of hardness is required.

SUMMARY

This chapter has given you a thorough overview of basic metallurgy. Remember, it is basic information only, and you will need to learn specific applications through experience and by further study in the appropriate technical manuals. Always ask a senior member of your division to explain anything in this chapter or in your work that you do not fully understand.

You have been introduced to stresses and strains, the structure, properties, and types of metals, and the ways in which metals are classified, marked, and tested. Go back now and review any of these areas that you do not understand.

CHAPTER 7

INTRODUCTION TO WELDING AND CUTTING

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

● *Identify the principle welding processes and define terms used in basic welding.*

● *Identify the various welding symbols.*

● *Describe the types and techniques of edge preparation in welding.*

● *Describe the purpose of temperature control during and after the welding process has been performed.*

● *Describe the pipe welding process, and identify the different classes of piping.*

● *Identify the principle cutting processes.*

● *Name the important publications concerning military standards and qualification tests with which a welder should be familiar.*

INTRODUCTION

One of the primary requirements for Hull Maintenance Technicians is to make various metal objects and structures. Most of these will require welding and cutting metal. Study and practical experience are both necessary to become an expert welder. This chapter contains essential background information that will help you to learn the welding processes and to qualify for advancement. Most of the terms, phrases, and processes discussed in this chapter are standardized, and are used in the Navy as well as by civilians in the welding trades. At times, the information in this chapter may seem complex, but you need a thorough knowledge of it to perform the duties of your job. Study this chapter carefully so you can effectively assist skilled welders and eventually become a good welder yourself.

WELDING PROCESSES

A master chart of welding processes is shown in figure 7-1. The term WELDING PROCESS means that you heat metal parts to a temperature that is high enough to join the metal parts by coalescence. It is done with or without the use of pressure or by the pressure alone, and it can be done with or without the use of filler metal. Coalescence means the growing together, or growth into one body, of the base metal parts. There are two basic requirements for coalescence: heat and intimacy of contact.

HEAT

The welding processes differ depending on the source of heat, the manner in which heat is applied or generated, and the intensity of the heat. The source of heat may be the combustion of a fuel gas
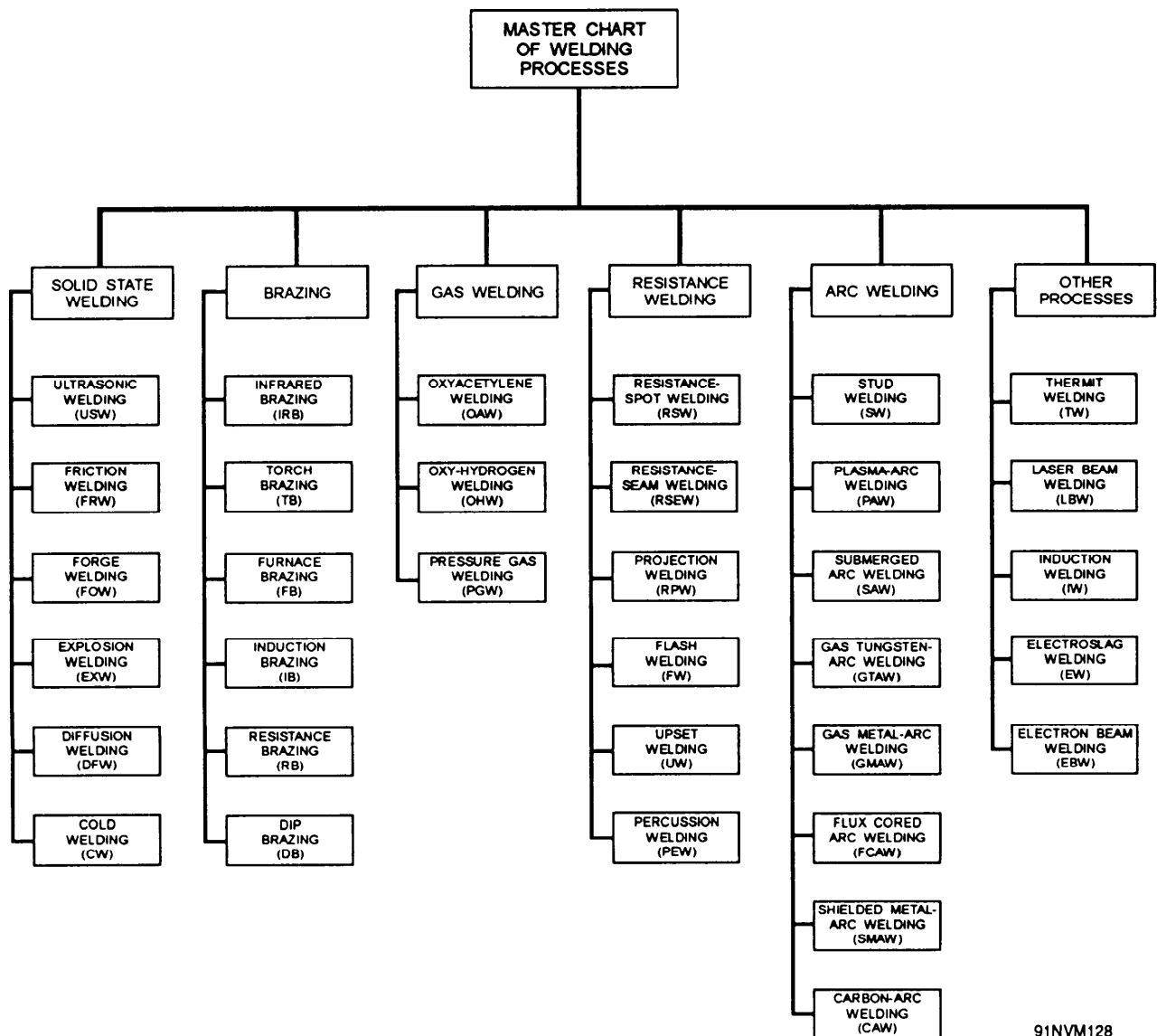
MASTER CHART OF WELDING PROCESSES

- **SOLID STATE WELDING**
  - ULTRASONIC WELDING (USW)
  - FRICTION WELDING (FRW)
  - FORGE WELDING (FOW)
  - EXPLOSION WELDING (EXW)
  - DIFFUSION WELDING (DFW)
  - COLD WELDING (CW)

- **BRAZING**
  - INFRARED BRAZING (IRB)
  - TORCH BRAZING (TB)
  - FURNACE BRAZING (FB)
  - INDUCTION BRAZING (IB)
  - RESISTANCE BRAZING (RB)
  - DIP BRAZING (DB)

- **GAS WELDING**
  - OXYACETYLENE WELDING (OAW)
  - OXY-HYDROGEN WELDING (OHW)
  - PRESSURE GAS WELDING (PGW)

- **RESISTANCE WELDING**
  - RESISTANCE-SPOT WELDING (RSW)
  - RESISTANCE-SEAM WELDING (RSEW)
  - PROJECTION WELDING (RPW)
  - FLASH WELDING (FW)
  - UPSET WELDING (UW)
  - PERCUSSION WELDING (PEW)

- **ARC WELDING**
  - STUD WELDING (SW)
  - PLASMA-ARC WELDING (PAW)
  - SUBMERGED ARC WELDING (SAW)
  - GAS TUNGSTEN-ARC WELDING (GTAW)
  - GAS METAL-ARC WELDING (GMAW)
  - FLUX CORED ARC WELDING (FCAW)
  - SHIELDED METAL-ARC WELDING (SMAW)
  - CARBON-ARC WELDING (CAW)

- **OTHER PROCESSES**
  - THERMIT WELDING (TW)
  - LASER BEAM WELDING (LBW)
  - INDUCTION WELDING (IW)
  - ELECTROSLAG WELDING (EW)
  - ELECTRON BEAM WELDING (EBW)

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Figure 7-1.—Welding processes.

such as acetylene or hydrogen in air or in oxygen; an electric arc; an electric, gas, or oil furnace; the resistance of metal to the flow of electric current; or a chemical reaction between a metal oxide and finely divided aluminum. The welding processes most commonly used aboard ship involve the combustion of a fuel gas, as in oxyacetylene welding and torch brazing; the use of an electric arc, as in metal-arc welding; and the resistance of metal to the flow of electric current, as in spot welding.

The intensity of heat applied or generated at the joint varies according to the metals being joined and to the welding process being used. All welding processes except brazing use temperatures high enough to melt the base metals. Brazing is the ONLY welding process in which the melting of the base metal is not necessary for coalescence. Brazing is similar to soldering, except that higher temperatures are used for brazing. The term SOLDERING is used to describe a joining process using nonferrous filler alloys melting below 800°F (427°C). Soldering is NOT considered a welding process. Brazing is a welding process using nonferrous filler alloys that have a melting point above 800°F (427°C) but below that of the base metal.

INTIMACY OF CONTACT

In the second basic requirement for coalescence, intimacy of contact, the welding processes may be divided into two groups: pressure processes and nonpressure processes. In PRESSURE PROCESSES, we get intimacy of contact by applying pressure while the contact surfaces are at a high enough temperature to allow plastic flow of the metal. In NONPRESSURE PROCESSES, a space is left between the surfaces to be joined. This space is filled, either progressively or all at once, with molten metal. The molten metal may be obtained from a filler metal (welding rod or electrode), by melting the surfaces to be joined, or by combining a filler metal and melted base metal.

All nonpressure processes involve fusion, and are often referred to as FUSION PROCESSES. However, this term is somewhat misleading since some pressure processes also involve fusion.

The various welding processes differ not only in the way coalescence is achieved, but also in their ability to produce a satisfactory joint in a given kind of metal under the conditions in which the weld must be made. Many factors influence the selection of a welding process for a particular application. Some important factors to be considered are the relative cost, the amount of welding required, the location and position of welds, the service conditions the welded structure must withstand, and the qualifications of the person who does the welding. Probably the most important single factor, however, is the weldability of the metal.

WELDABILITY

The term WELDABILITY means the capacity of a metal to be fabricated by a welding process into a structure that will perform its purpose satisfactorily. Weldability also means the degree of simplicity or complexity of the procedures and techniques used to produce welds with properties that are equal to or better than the properties of the base material. For example, mild steel can be welded by most welding processes, but the welds produced may not be equally satisfactory, and one method may be more complicated or more expensive than another. While it is possible to weld mild steel through the use of a variety of welding processes, some metals such as aluminum and its alloys can be satisfactorily welded with only a few welding processes. Mild steel does not require elaborate preparations, fluxes, and special techniques because its characteristics are such that the welding operation can be easily performed. Other metals require special preparatory steps, complex welding sequences, skillful use of a specific welding technique, and extensive heat treatments after welding.

Many factors influence the weldability of a metal. Here are some of the more important ones that must be taken into account and, insofar as possible, controlled: (1) the chemical composition of the metals involved (that is, the kind and percentage of elements present) and the effect of radical temperature changes on the various elements; (2) the expansion and contraction characteristics of the base metals; (3) the filler metal (welding rod or electrode); (4) the joint design; and (5) the welding procedure.

The Navy uses a large number of different metals and alloys. Each of these materials has characteristics or properties that make its use desirable for certain applications. The characteristics and properties of a given alloy are partly determined by the kind and amount of elements present. The effect welding has on these elements and their reaction during and after the application of heat have a tremendous influence on the weldability of the metal in question.

In steel, carbon is probably the most important element that limits weldability. Carbon gives steel hardenability; that is, when certain carbon steels are heated above a critical temperature and then cooled rapidly, they become much harder. At the same time they lose ductility. In fact, the metal may become extremely brittle. With few exceptions, the temperatures used in welding exceed the critical temperature of carbon steels. Further, more hardening may occur when the mass of relatively cold metal surrounding the weld area conducts heat away so fast that rapid cooling occurs. Thus, certain steels may become hardened by many of the welding processes.

When the percentage of carbon is less than 0.25 percent, its effect in producing hardness is slight. But when the carbon content exceeds 0.25 percent, or when such elements as manganese, vanadium, chromium, molybdenum, or titanium are present, along with a lesser carbon percentage, the weldability of the steel is decreased. Special steps should be taken to control preheat, interpass

temperature, postheat, and welding sequence. Otherwise, a satisfactory weld is likely to crack and to have reduced toughness and less strength than is required. For this reason, tool steels and certain alloys like carbon-molybdenum steel are less weldable than many other steels.

Steels contain certain impurities such as sulfur, phosphorus, hydrogen, nitrogen, and oxygen. If present in large enough quantities, these impurities may decrease weldability. For example, a steel to which about 0.10 percent sulfur has been added to improve machinability is difficult to weld because the weld has a tendency to crack. An excessive amount of phosphorus decreases the ductility of the steel and thus decreases the weldability of the metal. The presence of hydrogen in a steel, filler material, or flux may lead to cracks in the welds.

Stainless steels, high-chromium steels, and other special steels are less weldable than the plain low-carbon steels. The elements that give these special steels their desirable properties for some applications also have the effect of decreasing the weldability of the metals. To make these special steels weldable, the welding procedures, the filler metal, the fluxes, the preheat and postheat temperatures, and the welding sequence must be carefully selected. This is also true for many nickel, copper, and aluminum alloys.

In some metals, the heat of the welding process may cause certain elements with low-melting points to vaporize, thus reducing the amounts of those elements present in the weld zone. Nonferrous alloys containing lead, zinc, and tin are particularly subject to such losses from vaporization. These losses may seriously affect the properties of the joint by causing porosity or oxide inclusions that weaken the weld.

The weldability of a metal is also affected by its thermal conductivity. In general, metals with high thermal conductivity are difficult to weld because they transfer the heat away from the weld so rapidly that the required temperature cannot be maintained at the joint.

Changes in temperature cause a metal to expand or contract and that also affects weldability. When metals expand and contract at different rates, the internal stresses set up by these changes can cause the joint to crack immediately or to crack later under load.

Even when the weld joins identical metals, or metals having approximately the same coefficient of expansion, the expansion and contraction may not be uniform throughout all parts of the metal. These differences lead to internal stresses, distortion, and warping. Metal parts must be free to move or a special weld sequence must be used. When heat is applied or withdrawn, expansion and contraction set up high stresses, which in turn may cause trouble in the weld itself or in the adjacent base metal. In thin materials, uneven expansion and contraction may cause the metal to warp. In heavy material, the stresses set up may exceed the ultimate strength of the metal and cause cracking to occur in the weld or in the metal next to the weld, which is called the heat affected zone.

Even if the ultimate strength of the material is not exceeded by the stresses developed during welding, the combination of welding stresses PLUS the stresses developed when the material is placed in service may be enough to cause failure of the weld. It is for this reason that many materials are STRESS RELIEVED after welding.

Another factor that influences weldability is the filler material used. The wrong electrode or incorrect welding process will make welding difficult or impossible, and it may lead to failure of the part under service conditions. It is not always essential that the welding rod or electrode be of the same chemical composition as the base metal; the important requirement is that the combination of the filler metal and the base metal will make a satisfactory welded joint.

In some processes, the flux selected for use with a welding rod has important effects on weldability. Also, the electrode covering influences the weld obtained in certain steels. Molten steels have a tendency to absorb hydrogen from the surrounding atmosphere and to expel it when they solidify. Some types of electrode coverings send a lot of hydrogen into the atmosphere surrounding the arc and the molten puddle. This hydrogen is frequently enough to cause microscopic cracks in the heat-affected zone of some steels. To eliminate this problem, low-hydrogen electrodes have been developed to weld the newer high-tensile steels.

Joint design also influences the weldability of a metal. You need to consider several factors when you select a joint design. They include the welding

process, the thickness of the material to be welded, and the purpose the joint is to serve.

You can butt together thin sheets of metal without special preparation other than cleaning. But heavy plates must be beveled or grooved to make a satisfactory joint. Again, the design used is related to the purpose of the joint; that is, the way the load or stress is applied, the erosive or corrosive conditions it must resist, and the joint efficiency. The term JOINT EFFICIENCY is used to indicate the strength of a welded joint as compared with the strength of the unwelded base metal.

The terminology used to describe the various kinds of joints and the parts of a welded joint is discussed and illustrated later in this chapter. Details of joint designs for various applications and different welding processes are covered by specifications. At this point, you need to know only that joint design affects weldability.

As noted before, metals are not equally weldable with all welding processes. You should select a welding process on the basis of specifications and pertinent instructions from the Naval Sea Systems Command. For example, aluminum-base alloys are weldable by a number of processes. However, the Naval Sea Systems Command does not permit the welding of these alloys aboard ship by any welding process other than gas shielded-arc welding. These specifications and instructions must also be used to select base metals, filler metals, fluxes, and welding techniques.

Each of the welding processes has a technique or procedure peculiar to that process. Often the technique varies with the kind or size of the filler metal used or the kind of weld being made. The incorrect use of a technique, or the use of the wrong technique, may lead to defects that make the joint unsatisfactory.

TYPES OF JOINTS

Five basic types of welded joints are used in welded structures: butt, edge, tee, corner, and lap.

There are many variations, but every joint you weld will be one of these basic types. The joint area in each case is indicated by the shaded portion of the drawings in figure 7-2.

A BUTT joint is used to join the edges of two members lying in approximately the same geometric plane. The joint area is between the edges of the two members. This type of joint is frequently used in plate, sheet metal, and pipe work.

EDGE joints also may be used to join parallel members lying in the same plane, but as a rule one of the members is flanged. The edge joint in figure 7-2 shows that the members need not be in the same plane, as the members of a butt joint must be. With edge joints, the joint area is between the contacting surfaces of the members. While this type of joint has some applications in plate work, it is more often used in sheet metal work. In many cases, no filler metal is used in joining edge joints by the gas welding process. The edges are fused together, and the base metal supplies the weld filler metal. Occasionally the edge joint is used to join reinforcing plates to the flanges of I-beams and the edges of angles.

CORNER joints and TEE joints are used to join two members located at approximately right angles to each other. The joint area in each case is between the end of one member and the side or edge of another. The corner joint forms an L-shape (fig. 7-2). Corner joints are used to make tanks, boxes, box frames, and similar objects. Only
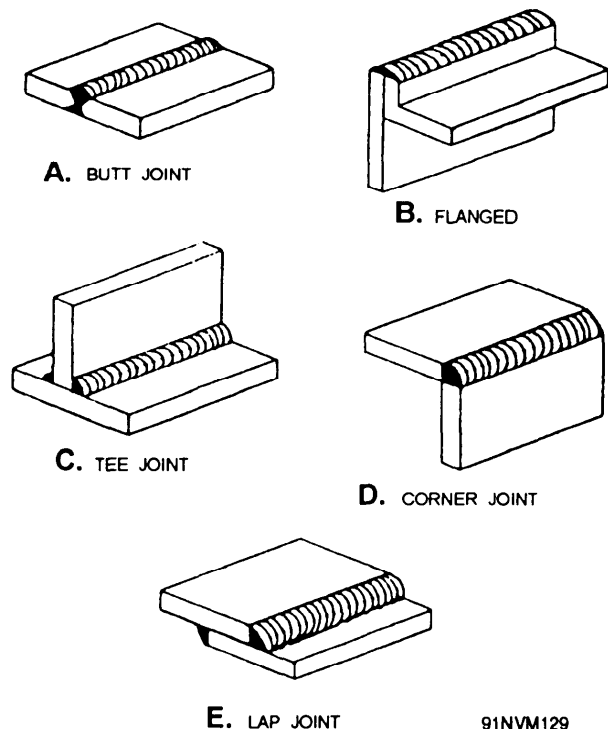

A. BUTT JOINT

B. FLANGED

C. TEE JOINT

D. CORNER JOINT

E. LAP JOINT   91NVM129

Figure 7-2.—Types of welded joints.

very-low-pressure tanks use corner joints because the root of the weld is in tension under load. The tee joint forms the shape of the letter *T*. Tee joints are used in many types of metal structures. The tee joint distributes stress more evenly throughout the structure.

The LAP joint is used to join overlapping members of a structure. The joint area of a lap joint is between the parallel surfaces of the joint members. Lap joints are often used in torch brazing processes where capillary action draws filler metal into the space between the hot surfaces. They are also used in many resistance welding processes, especially in sheet metal structures fabricated with spot welds.

TYPES OF WELDS

The types of welds most commonly used aboard ship are bead welds, fillet welds, tack welds, groove welds, plug welds, slot welds, spot welds, and seam welds. Another term that you will hear quite often is SEAL WELD. This term does not actually refer to any one type of weld; rather, it is any weld that is used primarily to obtain tightness.

Several types of bead and fillet welds are illustrated in figure 7-3. Usually a BEAD WELD (fig. 7-3, view A) is made by depositing filler metal in a single direction on an unbroken surface. However, it is also possible to make a bead without adding filler metal. In this case, the heat is applied and moved along steadily in one direction so that a molten puddle is formed in the base metal. Bead welds are used principally on butt joints and as a way of building up surfaces. The cross section of a bead weld usually has an oval shape.

A FILLET WELD is triangular in cross section. It joins two surfaces that are at approximately right angles to each other. Fillets are used to weld lap, tee, and corner joints. As shown in views B, C, and D of figure 7-3, some variations of the fillet weld are chain intermittent, staggered intermittent, and boxing.

A TACK WELD is a short weld deposit made to temporarily hold the parts to be joined in proper alignment for final welding. The sizes of tack welds are usually not specified, but they must not exceed 1 inch in length, and they must be as small as can be made, consistent with the size of the electrode being used. Tack welds must be incorporated into

A
BEAD WELDS

B
CHAIN INTERMITTENT FILLET WELD

C
STAGGERED INTERMITTENT FILLET WELD

D
BOXING FILLET
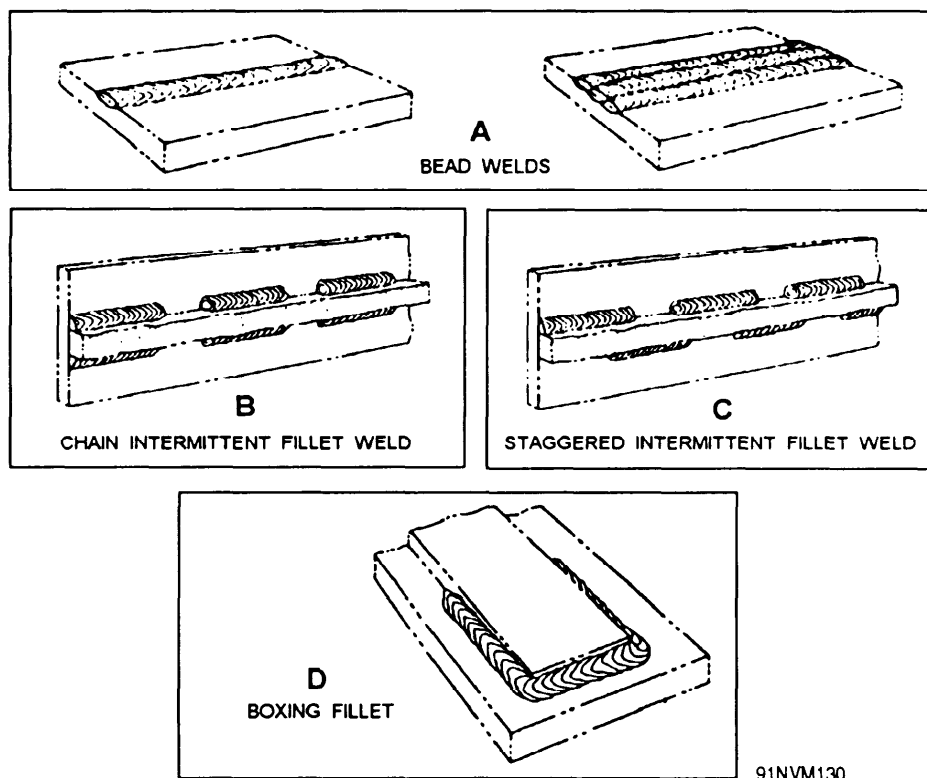
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Figure 7-3.—Bead and fillet welds.

the finished weld. Cracked or broken tack welds must be chipped or ground out before the joint is finally welded.

GROOVE WELDS are made in a specially prepared groove between two members to be joined. While the edge of a vertical plate of a tee joint is sometimes beveled for welding, grooves are most frequently used for butt joints in plate and pipe work. Standard grooves for plates joined with butt joints are illustrated in figure 7-4. Groove welds are designed to provide the required strength with a minimum amount of filler metal. Plate edges may be prepared for groove welding by shearing, machining, chipping, grinding, flame cutting, or flame grooving, depending on the metal. The selection of a particular groove design is governed by the thickness of the plate to be welded, the adaptability of the design to the structure, and the accessibility of the joint for welding. For example, a joint that can be welded from only one side requires a different groove design than a joint that is accessible from both sides.

PLUG WELDS and SLOT WELDS, as illustrated in figure 7-5, are used to join overlapping plates that are not otherwise accessible for welding. A plug weld is a circular weld made through one member of a lap or tee joint to join that member to another. The plug weld may or may not be through a hole punched or cut in the first member. If a hole is used in the first member, the plug weld may fill it completely or it may fill it only partially. A slot weld is similar to a plug weld, except that an elongated hole is made in the first member of the joint. The hole may be completely or partially filled with weld metal. Slot welds are often used to join one plate to the surface of another plate, and for other purposes where a fillet weld would not be economical or would not be a good design. Incidentally, a fillet weld made at the intersection of the edge of a slot and the exposed surface of the joining member is considered a fillet weld, NOT a slot weld.

SPOT WELDS and SEAM WELDS are common types of resistance welds. These welds are shown in figure 7-6. In resistance welding, coalescence is produced by a combination of pressure and the heat obtained from the resistance of the base metal to the flow of an electric current. A spot weld is used only when the parts of the joint

A SQUARE GROOVE WELD

B SQUARE GROOVE WELD

C SINGLE-BEVEL GROOVE WELD

D DOUBLE-BEVEL GROOVE WELD

E SINGLE-VEE GROOVE WELD

F DOUBLE-VEE GROOVE WELD

G SINGLE-J GROOVE WELD

H DOUBLE-J GROOVE WELD

I SINGLE-U GROOVE WELD

J DOUBLE-U GROOVE WELD
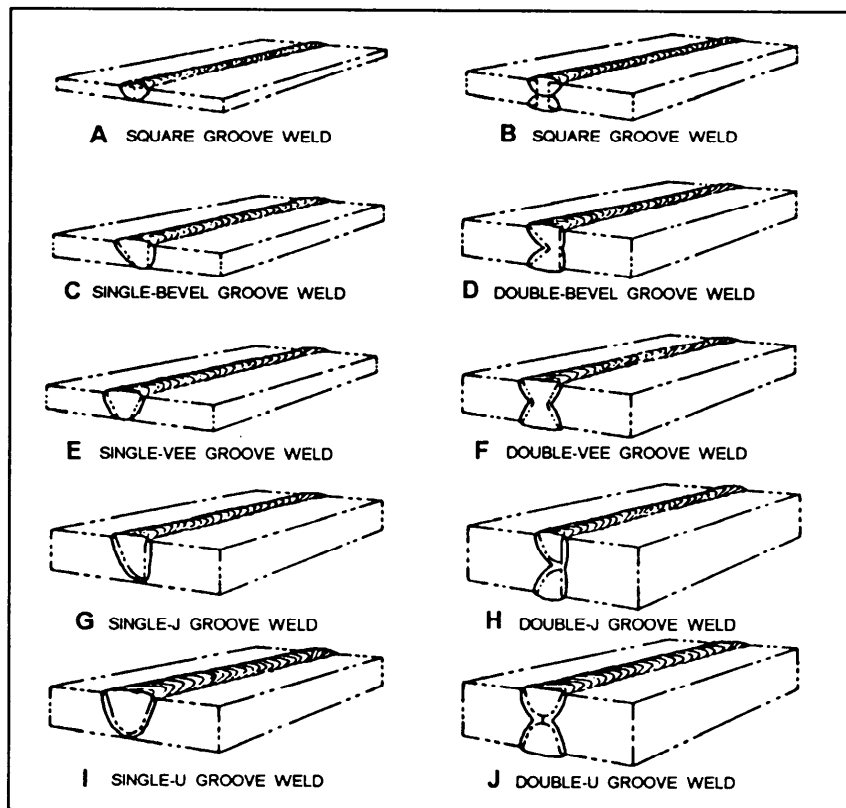
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Figure 7-4.—Standard groove welds.
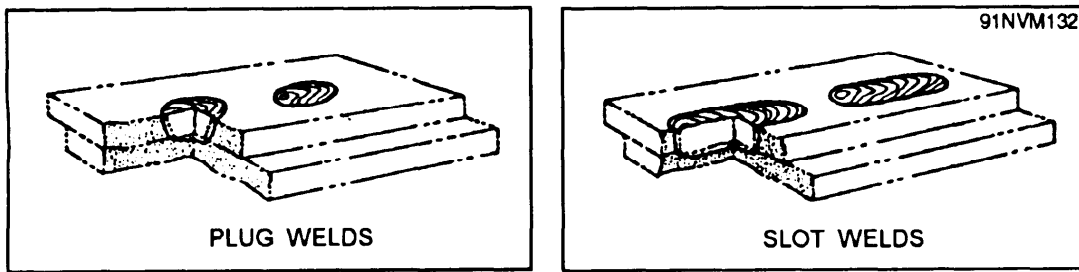
Figure 7-5.—Plug and slot welds.
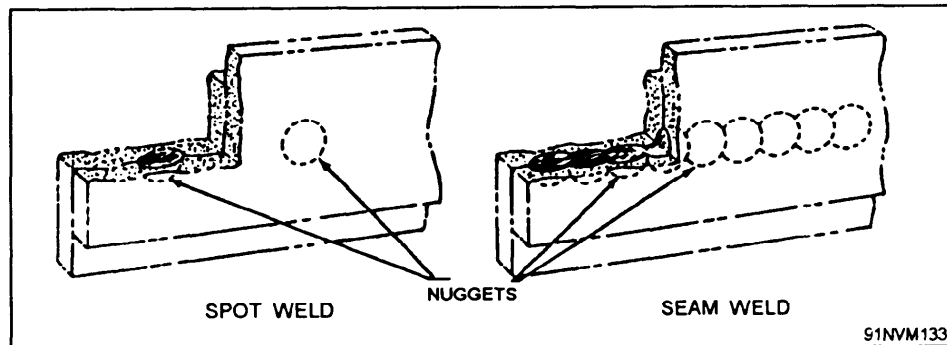
Figure 7-6.—Spot weld and seam welds.

overlap. The size and shape of the weld (often called the nugget) are determined by the size and shape of the electrode tips used in the welding machine. A seam weld is very much like a spot weld and may, in fact, be made as a series of overlapping spot welds, as shown in figure 7-6.

More commonly, however, seam welds are made with a wheel-type electrode.

PARTS OF WELDS

You should be familiar with the terms used to describe the parts of welds. Figure 7-7 illustrates the face and the toe on groove and fillet welds. The FACE is the exposed surface, on the side from which the weld was made, of a weld made by a gas or arc welding process. The TOE is the junction between the face of the weld and the base metal.

The ROOT of a weld includes the points at which the bottom of the weld intersects the base metal surfaces, as seen in cross section. Figure 7-8 illustrates weld roots.
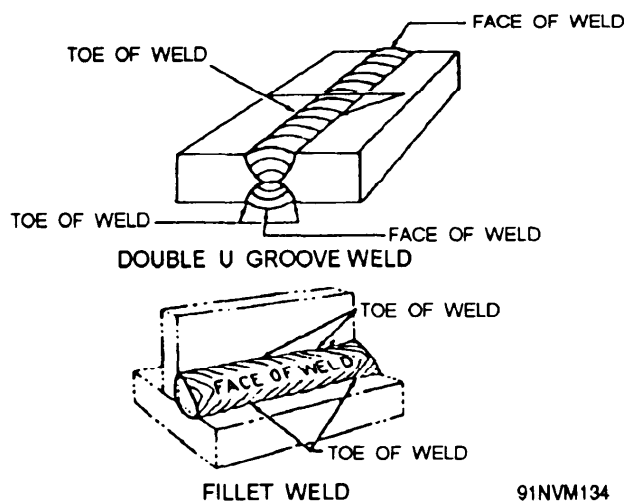
Figure 7-7.—Face and toe of groove and fillet welds.
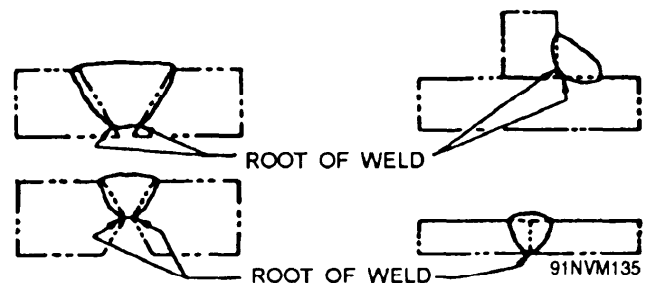
Figure 7-8.—Weld roots.

7-8

The legs and throat of a fillet weld are shown in figure 7-9. When we look at a triangular cross section of a fillet weld, the LEG is the portion of the weld from the toe to the root. The THROAT is the distance from the root to a point on the face of the weld along a line that would form a 90-degree angle with the weld face, as shown in figure 7-9.

Theoretically, the face is considered to form a straight line between the toes. If the face of the weld is convex or concave, it will not form a straight line between the toes. In that case, the actual face will be larger than the theoretical face, and the actual throat will be either larger or smaller than the theoretical throat. It should be noted that the terms LEG and THROAT apply only to fillet welds.

Several other terms are used to describe areas or zones of welds. Figure 7-10 illustrates the use of some of these terms. The BOND is the junction of the weld metal and the base metal. If weld metal is not used, the junction of the base metal parts is used. FUSION is the melting together of base and filler metal, or the melting of base metal only, that results in coalescence. The FUSION ZONE is the region of the base metal that is actually melted. The DEPTH OF FUSION is the distance that fusion extends into the base metal from the surface. Both the fusion zone and the depth of fusion are considered in terms of a cross section of the weld, as shown in figure 7-10. Another zone of interest to the welder is the HEAT-AFFECTED ZONE, also shown in figure 7-10. This zone includes that portion of the base metal that has not been melted but in which the properties and structure of the metal have been affected by the heat of welding or cutting. The extent of this zone varies with the thermal conductivity of the metal. The changes that occur within the area are related to the kind of metal being welded, the intensity and duration of heat, and the control embodied in the welding procedure.

PARTS OF JOINTS

To follow the specifications for any welding job, you must have a very clear knowledge of the terms used to describe parts of welds, and those used to describe parts of joints. The similarity in terms may lead to confusion. For example, the root of a weld is NOT precisely the same as the root of a joint. In other cases, it may be somewhat difficult to decide whether a term really refers to a part of a weld or to a part of a joint. In all cases, it is essential that you know EXACTLY what part, zone, or measurement is being referred to.
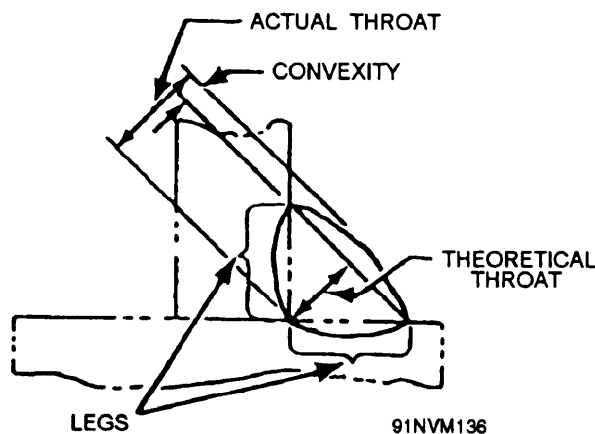
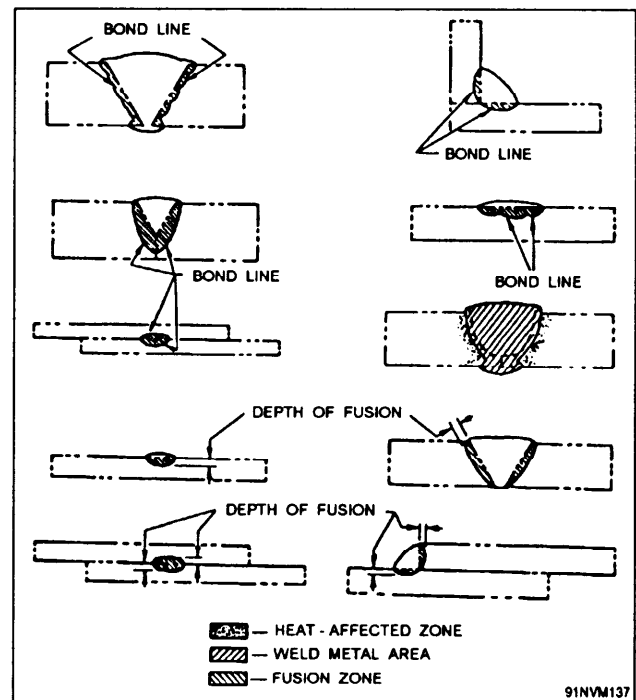Figure 7-9.—Legs and throat of fillet weld.

Figure 7-10.—Fusion zone, depth of fusion, heat-affected zone, and bond of weld.

Figure 7-11 shows that the GROOVE FACE is that surface of a member that is included in the groove. The ROOT of a joint is that portion of the joint where the members approach each other most closely. The root of a joint may be a point, a line, or an area when viewed in cross section. A given joint design may have a ROOT FACE or it may have a ROOT EDGE. A root face is the surface of the groove that is adjacent to the root of the joint. If the root face is of zero width, it is known as a root edge (fig. 7-11, view C).

Details of joint design involve the size of the groove and the space existing between the members of the joint. Specifications for joint design are expressed in terms of bevel angle, groove angle, groove radius, and root opening. Figure 7-12 illustrates the use of these terms.

The BEVEL ANGLE is the angle formed between the prepared edges of a member and a plane perpendicular to the surface of the member.

The GROOVE ANGLE is the included angle of the groove between the parts to be joined. For example, if the edge of each of the two plates to be joined were beveled to an angle of 30°, the groove angle would be 60°.

Figure 7-12.—Bevel angle, groove angle, groove radius, and root opening.

The GROOVE RADIUS is the radius of the curved portion of the opening at the bottom of the groove near the root of the joint. It exists only in special groove joint designs.

The ROOT OPENING refers to the separation between the members of the joint where the members are closest together.

The bevel angle, groove angle, and root opening of any joint will depend upon the thickness of material being welded, the kind of joint being made, and the welding process being employed. As a rule, oxyacetylene welding requires a larger groove angle than does manual metal-arc welding. Root opening is usually governed by the diameter of the filler material, which in turn depends on the thickness of the base metal and the position of welding.

Root penetration and joint penetration in groove welds are illustrated in figure 7-13. ROOT PENETRATION refers to the depth that a groove weld extends into the root of the joint. Root penetration is measured on the center line of the root cross section. JOINT PENETRATION refers to the minimum depth that a groove weld extends from its face into a joint, exclusive of any excess weld metal that is above the plate surface. Incidentally, this brings up another term you should know: REINFORCEMENT OF WELD is the term used to describe weld metal, on the face of a groove weld, that is in excess of the metal necessary for the specified weld size.

As may be seen from figure 7-13, the terms ROOT PENETRATION and JOINT PENETRATION often refer to the same dimension. This is the case in views A, C, and E of the

Figure 7-11.—Groove face, root face, and root edge.
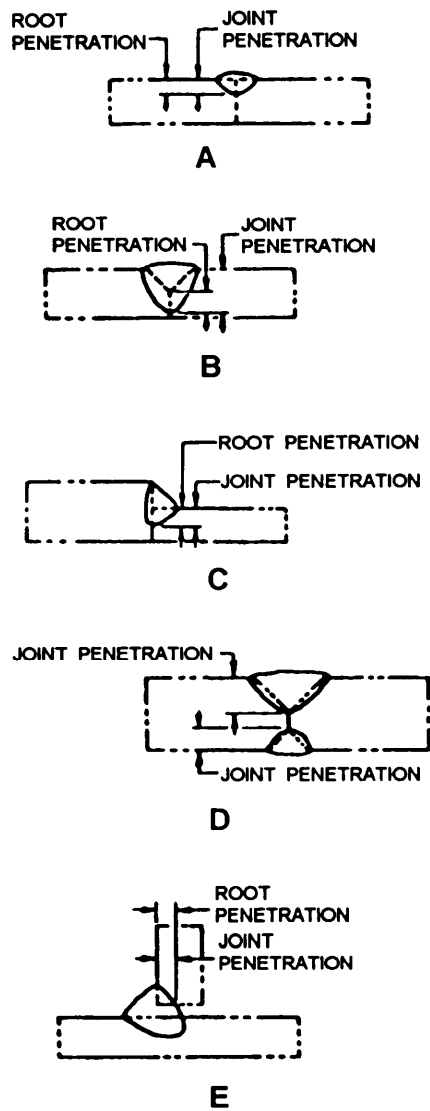
Figure 7-13.—Root penetration and joint penetration of groove welds.

Figure 7-14.—Flat, horizontal, vertical, and overhead positions for welding.

illustration. View B, however, shows how a difference may exist between root penetration and joint penetration. View D shows joint penetration only.

WELDING POSITIONS

Welding is performed in several different positions. In plate work, as shown in figure 7-14, these positions are flat, horizontal, vertical, and overhead. When welding is performed in the FLAT position (fig. 7-14, view A), the welder works from the upper side of the joint. In this position, the upper surface of the weld deposit metal is in a horizontal plane. Note that this is the case in both flat position fillet and groove welds.

In the HORIZONTAL position of welding (fig. 7-14, view B), the structural members of the joint are in an approximately vertical position while the line of weld (axis) is approximately horizontal. A horizontal position fillet weld is slightly different from that of a horizontal groove weld. Welding a fillet in the horizontal position involves depositing filler metal on the upper size of a horizontal surface and against an approximately vertical surface. The face of a fillet weld lies in a plane approximately 45° to the surfaces of the parts joined.

When welding is performed in the VERTICAL position (fig. 7-14, view C), the axis of the weld is in a vertical plane. In the vertical position, weld metal is usually deposited in an upward direction.

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In the OVERHEAD position (fig. 7-14, view D), welding is performed from the underside of the joint. The axis of the weld is in a horizontal plane, as is the axis of a flat position weld. But the overhead weld is, you might say, upside down if compared to the flat position weld. The terms FLAT, HORIZONTAL, VERTICAL, and OVERHEAD adequately describe the positions in which plate is welded. This terminology, however, does not describe the positions for welding pipe. When you weld pipe, you will weld in one of three positions: horizontal rolled position, horizontal fixed position, and vertical fixed position. Pipe welding positions are illustrated in figure 7-15. In each case, the terminology refers to the axial position and rotational freedom of movement of the pipe, not to the weld.

In HORIZONTAL ROLLED POSITION welds, the axis of the pipe is horizontal. The joint is made by welding in the flat position, at the same time rotating the pipe at a rate equal to the speed of filler metal deposition. Pipe welded in the horizontal rolled position is first carefully aligned and tack welded. Then it is placed in a jig, which facilitates rotation of the pipe. View A of figure 7-15 shows that all welding should be accomplished between points A and B.

The pipe axis in a HORIZONTAL FIXED POSITION weld is the same as in the horizontal rolled position weld. In this position, however, the pipe cannot be rotated. As a consequence, welding must be accomplished by progression through the overhead, vertical, and flat welding positions. When you are welding in the horizontal fixed position (fig. 7-15. view B), the weld is started at the bottom and progresses in increments upward to the top of the pipe-first on one side, then on the other.

In the VERTICAL FIXED POSITION, the pipe axis is vertical and held in a fixed position. The weld itself is made in the horizontal welding position (fig. 7-15, view C.)

PROCEDURES AND SEQUENCES

Whether large or small, simple or complex, the manufacture of any object requires careful planning. This is especially true when welding is employed to join parts into an integrated whole. One of the first decisions to be made regarding welding is the welding process to be used—that is, which of the processes is most applicable. But this is only the
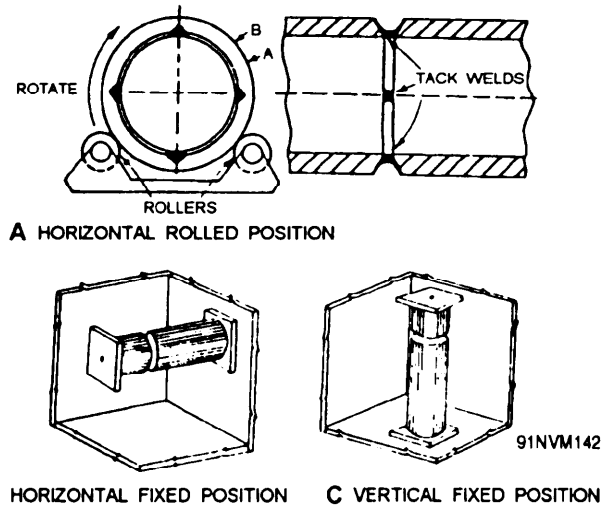

Figure 7-15.—Positions for welding pipe.

beginning. There are many details. Each must be worked out in such a way that the completed job serves the purpose for which it is intended.

To learn how to select a welding process, you must first understand the terms in which the job plans are expressed.

A single part of a structure consisting of several parts is called a COMPONENT. When a structure is made up of several components joined by welding, the structure is called a WELDMENT. Typical examples of weldments are gun mounts, machinery foundations, storage tanks, pressure tanks, frames, valve manifolds, and fabricated pipe fittings like crosses, tees, and elbows. The detailed plan worked out for producing the weldment is known as the WELDING PROCEDURE. The welding procedure specifies the kind of welding materials, joint design, preheat temperature, interpass temperature, postheat temperature, the chronological order and manner in which a series of joints are to be welded, and the way individual welds in the series are to be made. The chronological order of making the various welds in the weldment is called the WELDING SEQUENCE. Thus, the welding procedure spells out all the details for producing a given weldment with a predetermined welding process.

An important part of the welding procedure is the JOINT WELDING PROCEDURE. This term refers to the details pertaining to the materials, methods, and practices used to make a particular

joint in the weldment. Included in the joint welding procedure is the DEPOSITION SEQUENCE. This term refers to the order in which the weld metal in a given joint is to be deposited. Do not confuse the deposition sequence with a weld sequence; weld sequences will be discussed shortly. The deposition sequence may call for an intermittent weld or a continuous weld.

There are two types of INTERMITTENT WELDS. Both are fillet welds in which weld continuity is broken by unwelded spaces. The chain intermittent weld is illustrated in view B of figure 7-3, and the staggered intermittent in view C of figure 7-3. In chain intermittent welding, the increments or parts of the weld are approximately opposite each other. In staggered intermittent welding, the weld increments are staggered with respect to each other on opposite sides of a tee joint.

A CONTINUOUS WELD is one in which the completed joint contains weld metal throughout. In other words, there are no unwelded portions in the joint as in an intermittent weld. The continuous weld is made by one of two main weld sequences, either the continuous sequence or the longitudinal sequence.

A continuous sequence has a slightly different meaning than does a continuous weld. In a CONTINUOUS SEQUENCE, welding begins at one end of the joint and proceeds continuously to the other. The continuous sequence is the least complex of all the sequences. However, a continuous weld may be produced by a welding sequence other than the continuous sequence.

In a LONGITUDINAL SEQUENCE, the end result is a continuous weld, but the weld is not made by proceeding continuously from one end of the joint to the other. Here different parts of a joint are made at different times. The longitudinal sequence specifies the order in which the various increments of the continuous weld are to be made with respect to the entire length of the joint. The longitudinal sequence is completed by one of eight standard sequences, which includes the backstep, the wandering, the buildup, the block, the cascade, the progressive block, the wandering block, and the selective block. These sequences are used in welding to minimize distortion by controlling expansion and contraction.

When the longitudinal sequence is used to produce a continuous weld, you will normally use either the backstep sequence or the wandering sequence. The backstep and the wandering sequences are illustrated in figure 7-16.

In the BACKSTEP SEQUENCE, as shown in view A of figure 7-16, the weld does not begin at the end of the joint. Furthermore, the parts or increments of the weld are deposited in a direction opposite to that in which the entire joint is made. Increment length is usually specified. If it is not, you can determine the proper weld increment length by the following procedure.

Select an electrode of the proper type and diameter. Then, using the same methods that will be used in welding the joint, run an uninterrupted bead with one electrode on a piece of scrap metal. The length of the practice bead is the proper length for the increment. Thus, if your practice bead is 6 inches long, the first increment is started 6 inches from the edge of the plate. Successive increments would start 6 inches away from the previous weld increment. The backstep sequence is sometimes called a step-back sequence.

The WANDERING SEQUENCE, as shown in view B of figure 7-16, combines some of the features of both the continuous and the backstep sequences. In this sequence, weld increments are deposited in the same direction as the weld joint proper, as in a continuous sequence. However, as the illustration indicates, the order in which the weld increments are deposited is not progressive along the joint. Instead, gaps equal in length to that of the
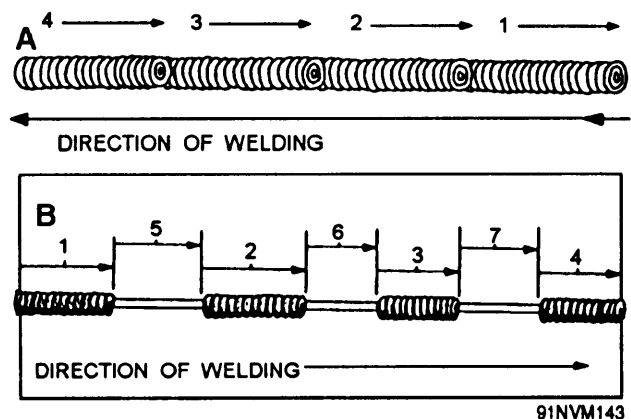

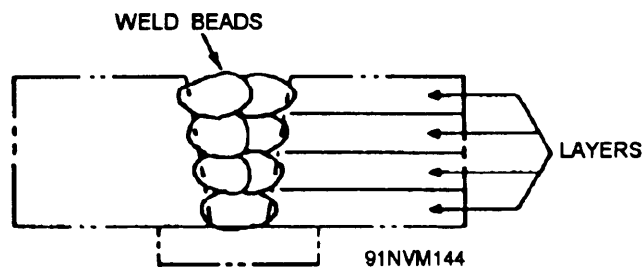Figure 7-16.—(A) Backstep sequence; (B) Wandering sequence.

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Figure 7-17.—Multiple-pass layers.

increment itself are left along the joint. Once the length of the joint has been welded in this manner, the welder fills the gaps, thus producing a continuous weld. The order in which the parts of the weld are made may differ from that indicated in view B of figure 7-16. Another order, such as 6-7-5-3-l-4-2, might be equally satisfactory. For this reason, the wandering sequence is often called the random or skip sequence. No matter which order is selected, the pattern must be predetermined. Increment length is determined in the way described for the backstep sequence. It is a good idea to lay out the joint increment lengths and number each portion according to the chronological order in which it is to be welded.

Thus far, we have considered only those sequences in which a single pass or weld bead is involved. (A PASS is a single progression of a welding operation along a joint or weld increment deposit. The result of a pass is a weld bead.) The sequences we will consider next consist of multiple-pass layer welds.

A LAYER consists of two or more weld beads. Figure 7-17 shows the use of multiple passes and layers in making a groove weld. The number of layers required to complete the weld is determined by the thickness of the metal being welded and the diameter of the welding rod being used.

Figure 7-18 illustrates block sequence, buildup sequence, and cascade sequence. Note that all of these sequences involve longitudinal sequence and multiple passes and layers. The BLOCK SEQUENCE, shown in view A of figure 7-18, is a longitudinal sequence having a specified buildup order. Individual sections or blocks of the continuous joint are partially or completely welded in an order somewhat like that of a backstep or wandering sequence before intervening sections are deposited. The term BUILDUP SEQUENCE refers to the order in which the weld beads of a multiple-pass weld are deposited with respect to the cross section of the joint. Thus, a buildup sequence is a part of any joint that requires layers of filler metal deposits to make the weld. View B of figure 7-18 shows a buildup sequence. The CASCADE SEQUENCE, shown in view C of figure 7-18, is a variation of the block sequence. It has a specified buildup order, but the weld beads are deposited in overlapping layers.
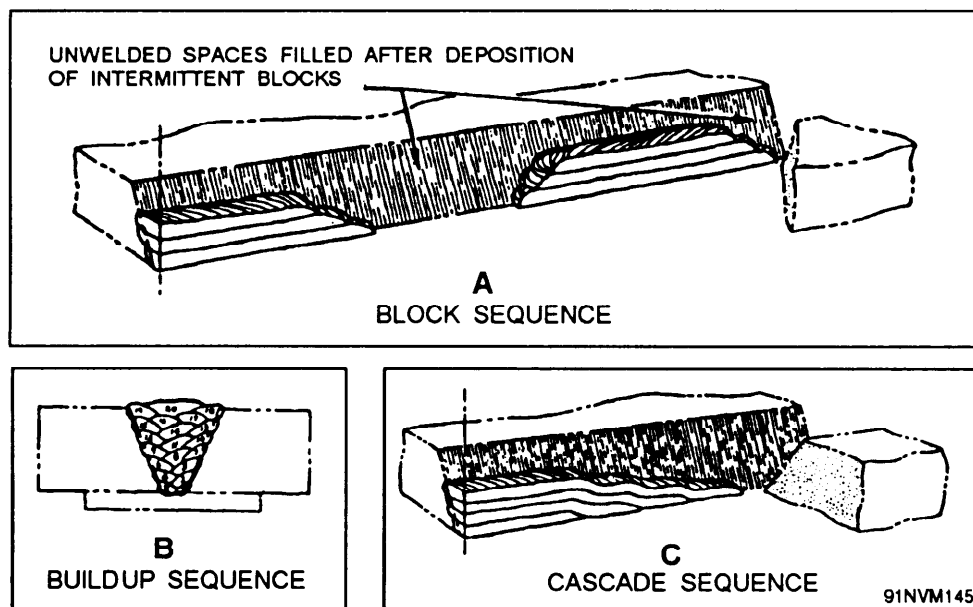

Figure 7-18.—Block, buildup, and cascade sequences.

There are several other variations of the block sequence. In the PROGRESSIVE BLOCK sequence, successive individual blocks of the continuous weld are completed progressively along the joint from one end to the other or from the center of the joint toward either end. Another variation is the WANDERING BLOCK. In this sequence, successive blocks are completed at random after several starting blocks have been completed. Still another variation is the SELECTIVE BLOCK SEQUENCE. Here the successive blocks are completed in a certain order so that a predetermined stress pattern is created within the joint.

WELD DEFECTS

Weld defects, like the welds themselves, must be described in standard terms. Common weld defects that you should be familiar with include incomplete fusion, inadequate joint and root penetration, spatter, overlap, undercut, root cracks, toe cracks, crater cracks, underbead cracks, voids, and inclusions.

Every welding design assumes that the specified extent of fusion and penetration will be obtained throughout the length of the joint. Welds such as those shown in figure 7-19 would be classified as defective because of incomplete fusion and lack of penetration.

Inadequate joint and root penetration is cause for rejection of a weld even if it is sound in all other respects. The strength required in a weldment is achieved only when the specified joint and root penetration is achieved.

Some visible weld defects are illustrated in figure 7-20. SPATTER is the term used to describe metal particles or globules that are expelled during
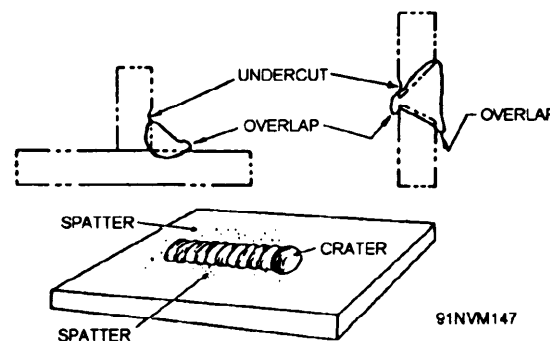

Figure 7-20.—Visible weld defects: spatter, overlap, and undercut.

welding and that do not form part of the weld. When spatter occurs, small balls of metal are stuck to the surface of the base metal along the line of weld. OVERLAP is a protrusion of the weld metal beyond the bond at the toe of the weld. An UNDERCUT is a groove melted into the base metal adjacent to the toe and not filled by weld metal. Both overlap and undercut are more serious than spatter, since either may seriously impair the strength of the weld. Overlap and undercut indicate that something is wrong with the welding techniques being employed or that something is wrong with the adjustment of the equipment.

Several kinds of cracks are classified as weld defects. Uneven expansion and contraction is usually the basic cause of cracks whether they are in the weld metal itself or in the adjacent heat-affected zone. One fairly common kind of crack is the CRATER CRACK. This occurs in the crater or depression at the termination of a weld bead in gas or arc welding.

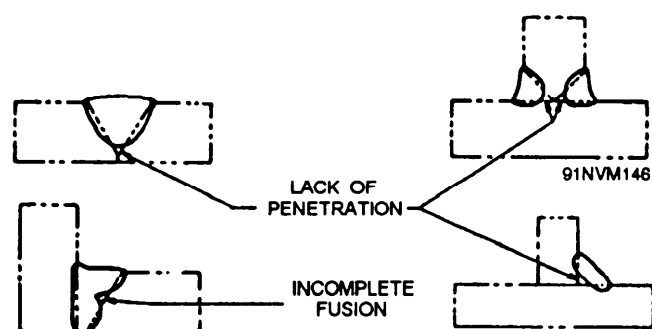Two other types of cracks are shown in figure 7-21. TOE CRACKS occur in the base metal, at

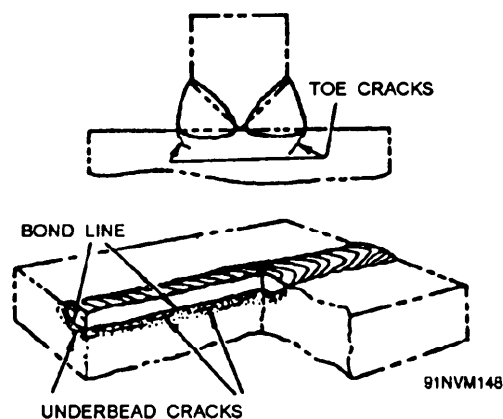Figure 7-19.—Examples of incomplete fusion and lack of penetration.

Figure 7-21.—Toe cracks and underbead cracks.

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the toe of the weld. UNDERBEAD CRACKS occur in the heat-affected zone underneath a bead, and do not extend to the surface of the metal. Underbead cracks can be detected either by X ray or ultrasonic examination.

ROOT CRACKS are similar to toe cracks except that they occur at the root of the weld. Root cracks may be in the weld metal or in the base metal.

VOIDS, also known as GAS POCKETS or BLOWHOLES, are another type of weld defect. The term POROSITY is used when there are a number of voids. Voids occur as the result of gas being absorbed during the welding and then trapped as the metal solidifies. The absorbed gas is usually hydrogen. Improper welding techniques, incorrect adjustment of equipment, or moisture in electrode coating may lead to the absorption of gas and the consequent formation of voids.

SLAG INCLUSION is the term used to describe the weld defect in which nonmetallic solid material is trapped in the weld metal or at the bond between the weld metal and the base metal. The presence of slag inclusions breaks up the homogeneity of the metal, thereby providing a point for the concentration of stresses. In some cases, the concentration of stresses thus developed leads to failure of the joint.

FILLER MATERIALS

The metals that are added during the welding process are known as filler materials or filler metals. In welding processes in which a space is left between the parts to be joined, filler metals provide the intimacy of contact necessary for coalescence. Filler materials used in welding processes include welding rods and electrodes.

The term WELDING ROD refers to a filler metal in wire or rod form. It is used in gas welding processes and in certain electric welding processes, such as gas tungsten-arc welding, in which the filler metal does NOT form a part of the electrical circuit. The only purpose of a welding rod is to supply filler metal to the joint.

The term ELECTRODE refers to the metal that, in electric welding, forms a part of the electrical circuit. In gas tungsten-arc welding,

electrodes melt off and are a source of the filler metal supply.

FLUXES

The welding or brazing of certain materials require the use of a flux to produce a sound joint. Fluxes are available as liquids, pastes, and powders. They have a melting point below that of the base and filler metals, and they are not incorporated into the weld. Their primary purpose is to prevent the formation of oxides on the weld joint before and during welding operations. Fluxes should never be used as a substitute for proper cleaning.

The application of fluxes will vary depending upon the type of welding being done. In silver brazing, the flux is applied directly to the joint with a brush. In other brazing operations, the filler metal is heated slightly and dipped into the flux.

The composition of fluxes is covered by a number of specifications. No one flux is satisfactory for all purposes. When the type of flux to be used is not otherwise specified, consult the *NSTM* or the latest NAVSEA instruction for the type of flux to use for a particular job.

Fluxes are not ordinarily required for oxyacetylene welding of mild steel and low-alloy ferrous metals. The oxides of these metals melt at a low temperature and flow away from the weld area. However, all brazing and soldering jobs on both ferrous and nonferrous metals require a flux. All oxyacetylene welding jobs on cast iron, cast steel, aluminum, copper, copper-base alloys, nickel, nickel-base alloys, high-chromium alloys, and silicon-bronze alloys also require a flux.

Several precautions must be observed when you are working with fluxes. Unless the base metal is properly cleaned and the correct flux applied to the joint, fluxing will hinder rather than aid in making the joint. Further, the flux must not be overheated or it will fail to serve its purpose. In addition, fluxes will also deteriorate if they are kept at brazing temperatures for too long a time. Nearly all fluxes give off fumes that may be toxic. For that reason, fluxes should always be used in a well-ventilated space. Any welding operation requires adequate ventilation, whether a flux is used or not.

EDGE PREPARATION

Joint edge preparation and proper spacing between the edges of the parts are important in any welding operation. The thickness of the plates and the joint design determine the amount of edge preparation required. Sheet metal is easily melted and does not require special edge preparation. The faces of the square edges can be butted together and welded. This type of joint can be used on sheets up to 1/16 inch thick. For metal thicknesses from 1/16 to 1/4 inch thick, a slight root opening between the parts is necessary to obtain complete penetration if welded from both sides. Plate over 3/16 inch thick and welded from one side requires beveled edges and a root opening as required by MIL-STD-22. For oxyacetylene welding on plate over 1/4 inch thick, the edges are beveled at an angle of 35° to 45°, making the groove angle from 70° to 90°. These edges can be prepared by flame cutting, shearing, flame grooving, machining, chipping, or grinding. In any case, the edge surfaces should be free of oxides, scale, dirt, grease, or other foreign matter.

Plate from 3/8 to 1/2 inch can be satisfactorily welded from one side only, but heavier sections should be welded by preparing the edges from both sides. Generally, butt joints prepared from both sides permit easier welding, produce less distortion, and ensure better qualities in the weld metal in heavy sections than do joints made from one side only.

EXPANSION AND CONTRACTION

Heat causes metals to expand, and cooling causes them to contract. Uneven heating will, therefore, cause uneven expansion, or uneven cooling will cause uneven contraction. Under such conditions, stresses are set up within the metal. These forces must be relieved, and unless precautions are taken, warping or buckling of the metal takes place. When cooling, if nothing is done to take up the stress set up by the contraction forces, further warping may result. If the surrounding cool sections of the metal are too heavy to permit this change in shape, the stresses remain within the metal itself. Such stresses may cause cracking while cooling or may remain within the metal until further force is applied, as when the piece is put into use.

Sheet metal (1/8 inch and less in thickness) has such a large surface area per unit of weight that heat stresses tend to produce warping or buckling of the sheet. This and the contraction effect encountered on long seams are the main points to be considered in sheet metal welding.

The effect of welding a long seam (over 10 or 12 inches) is to draw the seam together as the weld progresses. If the edges of the seam are placed in contact with each other throughout their length before welding starts, the far ends of the seam will actually overlap before the weld is completed.

One way of overcoming this effect is illustrated in figure 7-22. The two pieces to be welded are placed with an increased allowance at the far end, and as the welding progresses, the two pieces are drawn together. This allowance is generally one metal thickness per foot of seam.

Another method of controlling expansion and contraction is by the use of chill bars. Heavy pieces of metal are placed on either side of the weld. They absorb the heat and keep it from spreading across the whole surface area. Copper is commonly used for chill bars because of its ability to absorb heat rapidly. Welding jigs sometimes use this same principle to remove heat from the base metal. (See fig. 7-23.)

TEMPERATURE CONTROL

The control of temperature before, during, and after welding is often a matter of vital importance. Preheating and postheating are specified for many welds on many types of metals. Control of interpass temperature is important in all multipass welds.
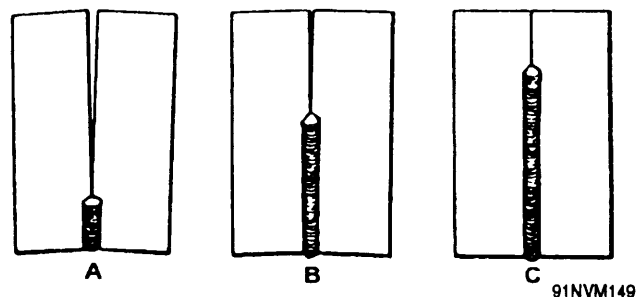

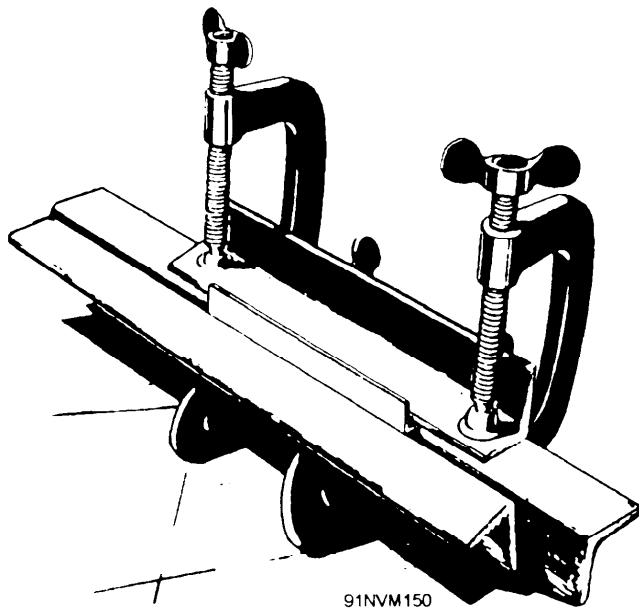**Figure 7-22.—Allowance for a straight butt weld.**

Figure 7-23.—Example of the use of jigs and chill bars.

Oxyacetylene or propane torches and electric induction or resistance coils may be used for preheating and postheating. Portable electric heaters are furnished to repair ships, tenders, and other ships and stations that normally fabricate items made of carbon molybdenum steel and chromium-molybdenum steel. The complete unit consists of control devices mounted on a portable panel, electrical supply connections, heater cable leads, and heater coils.

PREHEATING is the application of heat to the base metal before a welding or cutting operation is performed. Preheating is not required for all welds. When required, the preheat temperature and the length of time the temperature must be held (hold time) is specified in the welding process instruction being used. The preheat temperature and the hold time depend upon the chemical composition of the metal, the thickness of the metal, and to some degree upon the welding method and the type of welding rod or electrode used. Some alloys are more successfully welded without any preheat. Because of the wide variations in preheat requirements, you must follow the welding specifications for each job precisely.

INTERPASS TEMPERATURE is the temperature of the deposited weld metal before the next pass can be made. The interpass temperature (minimum or maximum as specified in the welding process instruction) will vary according to the composition and thickness of the metal being welded.

POSTHEATING is done primarily for the purpose of relieving stresses in the metal after it has been welded. The temperature, the hold time, and the cooling rate are specified for each job where postheating is required. In general, slow cooling is essential for stress-relieving. If the metal is cooled rapidly, new stresses will develop and thus defeat the purpose of the postheating.

Requirements for stress-relieving depend upon the composition of the metal, the thickness of the metals to be joined, and the complexity of the weldment. In some cases, stress-relieving may be specified for a partly welded joint. Stress relief is usually required for welded joints that will be subjected to high pressure. Tables to be used as guides for temperature control are contained in MIL-STD-278.

WELDING PIPING

The requirements for fabricating piping by welding vary according to the class of piping involved. MIL-STD-278 establishes four classes of piping: P-1, P-2, P-3, and P-LT.

CLASS P-1 includes all piping used for services where the pressure exceeds 300 psi or the temperature exceeds 650°F. It also includes ALL piping systems used for conveying deadly gases or liquids and hydrogen peroxide (regardless of the pressures and temperatures in these systems), except where such systems are covered by classes P-2 or P-3. Examples of class P-1 piping include steam lines, hydraulic systems, steam escape piping below decks, boiler generating tubes, boiler superheater and economizer elements, and other pressure-retaining tubes and piping. Class P-1 piping does NOT include nozzle and root connections to pressure vessels where such connections are covered by pressure vessel classifications.

CLASS P-2 includes piping used for services where the pressure does not exceed 300 psi and the temperature does not exceed 650°F. It also includes escape piping above decks. Class P-2 piping does NOT include piping covered by class P-3.

CLASS P-3 includes all brazed piping of unlimited pressure and a maximum temperature of 425°F. Fabrication and inspection of brazed piping should be according to the requirements of NAVSHIPS 0900-001-7000.

CLASS P-LT includes all piping of design pressure greater than 50 psi and service temperature for minus 20°F and below.

The following general considerations apply to all pipe welding:

—Whenever possible, weld pipe in the horizontal rolled position. It is much easier to weld near the top of the pipe than it is to work through the overhead and vertical positions. By using the horizontal rolled position, you get the advantages of increased speed and the likelihood of a sound weld.

—Be sure the pipe is carefully aligned.

—Tack welding is used in practically all pipe welding. The number of tack welds needed is determined by the diameter of the pipe. The size of the tack welds is determined by the wall thickness of the pipe. For 1/2-inch pipe, two diametrically opposite tack welds are used. On 12-inch pipe, you will need six tack welds. Four welds are usually sufficient for the common pipe sizes. Tack welds are generally incorporated into the finished weld; therefore, the material used for tack welding MUST be the same as the filler metal. Any tack weld that contains cracks or other defects must be removed by chipping, grinding, or gouging before the final weld is made.

—On circumferential butt welds, provide a weld buildup of 1/16 to 3/32 inch, depending upon wall thickness and pipe size.

—In multipass welding, remove all slag from each bead before depositing the next bead.

—For some welds, peening is permitted as a means of correcting distortion and minimizing residual stresses. However, peening MUST NOT be done on single bead or single layer welds nor on the last layers of multiple layer welds.

Specific information pertaining to welding on the various classes of piping is given in the following sections.

P-1 CLASS PIPING

The shielded metal-arc and gas tungsten-arc welding processes must be used for the shipboard welding of P-1 class piping that is 0.109 inch or more in wall thickness and for the shop welding of P-1 piping that is more than 0.083 inch in wall thickness. At least two layers of weld metal must be applied around all joints in this piping.

Stress relief heat treatment is generally done after welding on P-1 class piping. Factors that determine whether or not stress relief is necessary include the carbon content of the alloy, the chromium content, the thickness of the joint, and the size of the pipe (iron pipe size [ips]). Also, stress relief is required for some materials in P-l class piping if preheat and interpass temperatures of 200° to 300°F were not maintained.

All welds in P-l piping must be tested hydrostatically. Most of these welds must also be inspected by radiographic, magnetic particle, or liquid penetrant inspection. Requirements for welding and testing welds in P-l piping are normally covered by the applicable welding procedure or military standard. Use *NSTM,* chapter 074, volume 1, as a starting document. It will refer you to other applicable documents, such as MIL-STD-278 for fabrication and inspection, MIL-STD-271 for nondestructive test requirements, MIL-SD-22 for joint design, and numerous military specifications for material requirements. All of these documents are a necessary part of welding on P-l piping.

For more in-depth information on a particular job, refer to the applicable military standards, or procedures designated for use by NAVSEA.

P-2 CLASS PIPING

The manual shielded metal-arc process is used for the shipboard welding of P-2 class piping that is 0.109 inch or more in wall thickness and for the shop welding of P-2 piping that is 0.083 inch in wall thickness. Gas tungsten-arc welding may be used on P-2 piping that is less than 0.109 inch thick.

Thermal stress relief is required for P-2 class piping welds in carbon steel and carbon

molybdenum alloy steels that have over 35 percent carbon.

All welds in P-2 piping must be inspected during the hydrostatic test of the piping and must be radiographed if it is required by the plans or specifications.

P-LT CLASS PIPING

In general, the manual shielded metal-arc process is used for the shipboard welding of P-LT class piping that is 0.109 inch or more in wall thickness and for the shop welding of P-LT class piping that is 0.083 inch in wall thickness.

The tests and inspections for P-LT class piping are generally the same as those for P-l class piping. Use the applicable documents that cover joint designs, welding procedures, stress-relieving, and nondestructive tests and inspections for each job as required.

P-3 CLASS PIPING

The requirements for P-3 class piping are equally as important as those for P-l, P-2, and P-LT piping. P-3 piping systems are assembled by silver brazing. Filler materials and fluxes must be selected on the basis of the metals to be joined.

The fabrication and inspection of all P-3 piping must be according to NAVSEA 0900-LP-001-7000, *Fabrication and Inspection of Brazed Piping Systems.* After the joint is cooled, all accessible sections of the joint are to be cleaned to remove any scale or flux that may be present.

In addition to being hydrostatically tested, all silver-brazed joints in P-3 class piping 2 inches ips and over must be ultrasonically tested. On

Figure 7-25.—Basic resistance weld symbols.

submarines, all silver-brazed joints 1/2 inch ips and above must be ultrasonically tested.

WELD SYMBOLS AND WELDING SYMBOLS

Special symbols are used on drawings to show the kinds of welds to be used. These symbols have been standardized by the American Welding Society and the Department of Defense. The basic reference in this field for Navy welders is the American Welding Society Standard, AWS A2.4-79. AWS A2.4-79 supersedes AWS A2.0-68, which formerly was the basic reference for the Navy welders. Although there is no need for you to memorize all the welding symbols given in AWS A2.4-79, you should be familiar with the basic weld symbols and with the standard location of all eight elements of a welding symbol.

The distinction between a weld symbol and a welding symbol should be noted. A WELD SYMBOL is a basic weld symbol used to indicate the type of weld. Thus, the basic weld symbols shown in figures 7-24 and 7-25 are weld symbols. The supplementary weld symbols shown in figure 7-26 are used when necessary in connection with the basic weld symbols. In figures 7-24, 7-25, and 7-26, view A, shows the symbols that were listed in AWS

Figure 7-24.—Basic arc and gas weld symbols.

Figure 7-26.—Supplementary weld symbols.

A2.0-68. Some of the symbols, but not all, have been changed by AWS A2.4-79. View B shows the new symbols for those changed. No figure is shown in view B for those symbols that were not changed. You should be aware that some drawings available may still show the symbols that were changed.

An assembled WELDING SYMBOL consists of the following eight elements (or as many of these elements as are required): (1) reference line, (2) arrow, (3) basic weld symbols, (4) dimensions and other data, (5) supplementary symbols, (6) finish symbols, (7) tail, and (8) specification, process, or other reference. The finish symbols indicate the method of finish, not the degree of finish. The letter C is used to indicate finish by chipping, *M* indicates machining, and G indicates grinding.

The elements of a welding symbol have standard locations with respect to each other, as shown in figure 7-27.

SAFETY PRECAUTIONS

Safety precautions for welding may be considered as falling into three general categories: (1) precautions with respect to the location of the welding; (2) precautions concerning the operation of equipment; and (3) precautions related to the safety of personnel.

The safety precautions given here are general in nature and should be supplemented by study of the precautions given in chapter 1 of this manual and NSTM, chapter 074, volume 1.

LOCATION OF WELDING

A first consideration for safety in welding is the location and peculiarities of the space in which the welding operation is to be performed. Welding and cutting may be performed ONLY in locations specifically designated for this purpose, unless approval of the job and the precautions taken to eliminate fire and explosion hazards have been obtained from the proper authority.

Fire and explosion hazards are eliminated by removing or protecting combustible or explosive materials or vapors, and by taking the precautions necessary to prevent a reaccumulation of such materials. The methods for making a space safe for welding and the tests used to ensure that a space is free of fire and explosion hazards are the responsibility of the gas-free engineer, whose duties
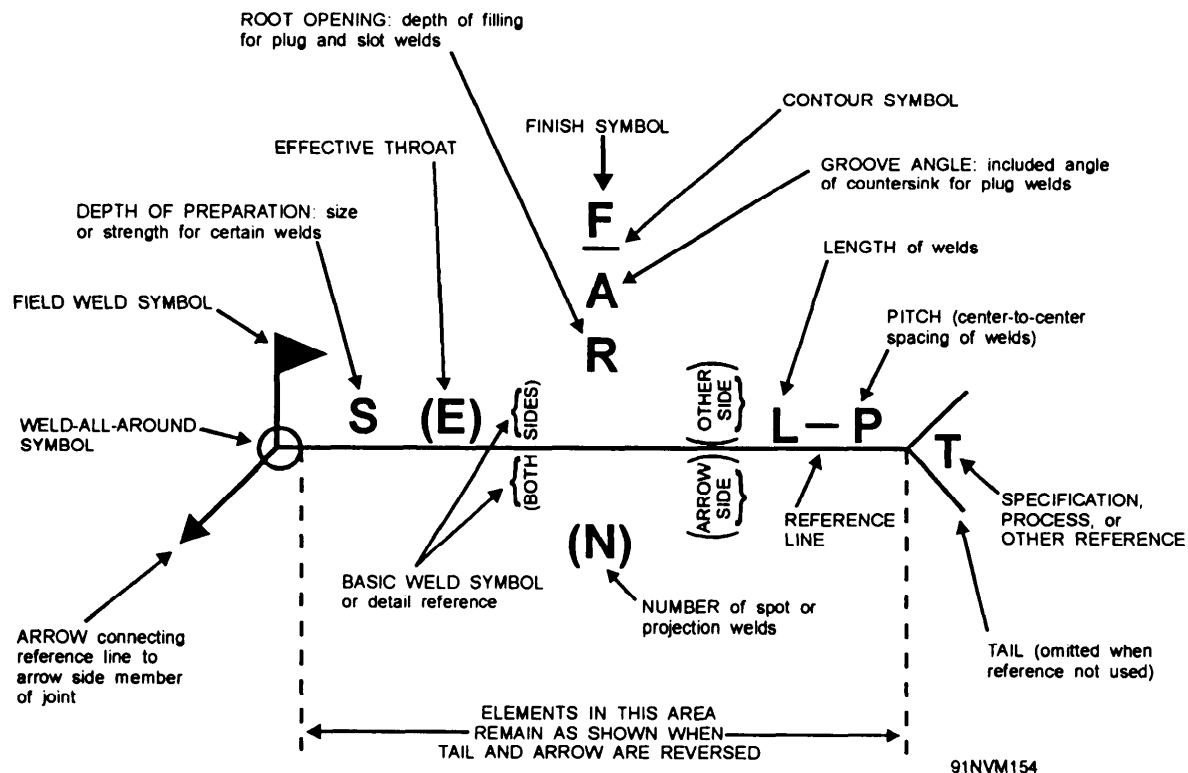

Figure 7-27.—Standard location of elements on a welding symbol.

are described in *NSTM,* chapter 074, volume 3. Keep in mind that welding MUST NOT be performed in any location outside the shop unless the necessary precautions have been taken and approval has been obtained. Any compartment, room, tank, or space adjacent there to which contains or which has contained flammable or explosive materials, liquids, or vapors must be made safe, tested, and proclaimed safe before you can weld in such a space. These restrictions also apply to closed drums, tanks, and similar containers.

When welding is being done, a fire watch must be posted in the vicinity, particularly when flammable or explosive materials are exposed. If a fire hazard exists on both sides of a bulkhead or deck, fire watches must be stationed on both sides with appropriate types of fire extinguishers. For example, if the only combustible material within range of the sparks or heat from welding or cutting operations is bitumastic waterproofing, a CO_2 extinguisher may be adequate. In a small space with a very small access opening, however, the operator might not be able to get out quickly in the event of fire. The use of CO_2 would be dangerous in this case; the use of water from a 1 1/2-inch waterline or water pump tank would be preferable. If the insulation on some electrical equipment is the only combustible material present, the use of water would be more dangerous than the fire itself. In this situation, CO_2 would be used. In each case, it is necessary to consider what kind of fire might occur and to provide the appropriate equipment to combat it. The fire watch must remain on station at least 30 minutes after a job has been completed to make sure that there is no smoldering fire.

Adequate ventilation must be provided in all spaces in which welding is being done and to eliminate health hazards such as gases, fumes, and dust caused by the welding operation. Any welding operation requires that the operator, helper, or fire watch wear approved respirators regardless of the amount of ventilation provided. When welding or cutting operations are performed on lead-bearing steels, lead-coated or cadmium-coated metals, or metal covered with paint containing lead or cadmium, an air-line mask should be worn even if the work is done in the open air or in a well-ventilated space.

When welding is performed on uncoated ferrous metals, a minimum space allowance of 10,000 cubic feet per operator or three complete air changes per hour must be provided. When welding is performed on galvanized metals, brass, bronze, and some other metals, the ventilation requirements increase by at least 10 percent. For welding performed in a confined space, positive steps are necessary to ensure the elimination of health hazards. In addition, some conditions, like welding inside a tank, make it necessary for the welder to wear an air-line mask.

As a welder, you must consider as unsafe every closed compartment or poorly ventilated space, all tanks, cofferdams, voids, and similar spaces, until the gas-free engineer has inspected the space and has indicated that adequate precautions have been taken. When the condition of the space has been determined, the gas-free engineer posts a tag describing the condition of the space. The tag posted includes complete information as to whether or not the space is safe for persons and whether or not it is safe for hot work. The information on the tag is expressed in one of the following ways, depending on the condition of the space:

● NOT safe for persons—NOT safe for hot work

● Safe for persons—NOT safe for hot work

● Safe for persons—Safe for hot work

● INERTED—NOT safe for persons INSIDE—Safe for persons and hot work OUTSIDE

● PRESSED UP (with water or oil)—Safe for persons and hot work OUTSIDE

The term *inerted* means that a nonflammable gas (usually CO_2) has been introduced into the space and that the concentration of the gas is sufficient to reduce the oxygen content of the space to a level that will not support combustion. The term *pressed up* means that the space has been entirely filled with water or oil.

When it is necessary for welding or cutting to be performed in any confined space that has a small exit, all heavy equipment, such as gas cylinders and welding generators, must be left on the outside. An attendant who can observe the welder at all times must also be stationed on the outside of the space so that in an emergency the attendant can shut off the gas or the electric current and provide such

other help as the situation demands. If the welder must enter the space through a manhole or other small space, a lifeline and safety belt must be attached to the welder's body so that the welder can be quickly removed in an emergency. This equipment must be attached in such a way that the welder's body cannot be jammed in the small opening.

The discussion thus far has been primarily concerned with compartments and tanks that are part of the ship's structure. Certain special precautions should be noted for welding or cutting on any hollow metal article, whether the work is performed in or out of a welding shop.

Before allowing any welding or cutting to be done, be sure that if the hollow metal article has ever held a flammable substance, it is cleaned and made safe. Even a trace of flammable material in a drum, tank, or other hollow article would constitute a tremendous hazard. A container that has held a flammable substance may be cleaned with steam if the substance is easily vaporized. For removing heavy oils, a strong solution of caustic soda or a similar chemical is usually used. Thorough rinsing of the article is necessary. After a container has been cleaned, it should (if possible) be filled with water, carbon dioxide, or nitrogen. This precaution should be taken since it may be impossible to remove all traces of oil or grease from the seams or corners of the container.

Hollow metal articles must be vented before being welded or cut, whether or not they have ever contained a flammable substance. If they are not vented, the increase in air pressure that occurs when heat is applied may be sufficient to cause an explosion.

OPERATION OF EQUIPMENT

Safety precautions for the operation of welding equipment vary considerably because of the different types of equipment involved. Consequently, only general precautions pertaining to gas welding and to metal-arc welding are given here. Further precautions may be found in chapter 1 of this manual, in the references already mentioned, and in the technical manuals furnished by the manufacturers of the equipment.

Precautions for the operation of gas welding equipment include the following:

—Use only approved apparatus that has been examined and tested for safety.

—Stow all cylinders carefully according to prescribed stowage procedures. Cylinders should be stowed in dry, well-ventilated, well-protected places, away from heat and combustible materials. Do NOT stow oxygen cylinders in the same compartment as acetylene or other fuel gas cylinders. All cylinders should be stowed in an upright position rather than horizontally. If acetylene cylinders are not stowed in an upright position (valves at top), they must not be used until they have been allowed to stand in an upright position for at least 2 hours.

—Do not allow anyone to tamper with cylinder safety devices.

—When cylinders are in use, keep them far enough away from the actual welding or cutting so they will not be reached by sparks, hot slag, or flame.

—Never place a cylinder in such a position that it could form part of an electrical circuit.

—Never interchange hoses, regulators, or other apparatus intended for oxygen with those intended for acetylene.

—Never attempt to transfer acetylene from one cylinder to another, to refill an acetylene cylinder, or to mix any other gas with acetylene.

—Keep the valves closed on empty cylinders.

—Do not stand in front of cylinder valves while opening them.

—When a special wrench is required to open a cylinder valve, leave the wrench in position on the valve stem while the cylinder is being used so that the valve can be closed rapidly in an emergency.

—Keep oxygen cylinders and fittings away from oil and grease. Even a small amount of oil or grease may ignite violently, with explosive force, in the presence of oxygen. NEVER lubricate any part of an oxygen cylinder, valve, or fitting.

—Do not drop cylinders. Do not handle them roughly. Rough handling may cause a cylinder valve

to break off, and the sudden release of gas from a full cylinder may cause it to take off like a rocket.

—Always open cylinder valves slowly. (Do not open the acetylene cylinder valve more than 1 1/2 turns.)

—Close cylinder valves before moving cylinders.

—Never attempt to force unmatching or crossed threads on valve outlets, hose couplings, or torch valve inlets. The threads on oxygen regulator outlets, hose couplings, and torch valve inlets are right-handed; for acetylene, these threads are left-handed. The threads on acetylene cylinder valve outlets are right-handed, but have a pitch that is different from the pitch of the threads on the oxygen cylinder valve outlets. If the threads do not match, the connections are mixed.

—Always use the correct tip or nozzle and the correct pressure for the particular work involved. This information should be taken from tables or worksheets supplied with the equipment.

—Do not allow acetylene or acetylene and oxygen to accumulate in confined spaces. Such mixtures are highly explosive.

—Keep a clear space between the cylinders and the work so that the cylinder valves may be reached quickly and easily if necessary.

—When lighting the torch, open the acetylene valve first and ignite the gas while the oxygen valve is still closed. Do not allow unburned acetylene to escape and accumulate in small or closed compartments.

—When extinguishing the torch, close the acetylene valve first and then close the oxygen valve.

—When welding or cutting is stopped for a period of 15 minutes or more, or when the operator leaves the area, the equipment must be secured.

Precautions for the operation of metal-arc welding equipment include the following:

—Use only approved welding equipment, and be sure that it is in good condition.

—Before starting to work, make sure that the welding machine frame is grounded, that neither terminal of the welding generator is bonded to the frame, and that all electrical connections are securely made. The ground connection must be attached firmly to the work, not merely laid loosely upon it.

—When using portable machines, take care to see that the primary supply cable is laid separately so that it does not become entangled with the welding supply cable.

—When stopping work for any appreciable length of time, be SURE to de-energize the equipment. When not in use, the equipment should be completely disconnected from the source of power.

—Keep welding cables dry and free of oil or grease. Keep the cables in good condition, and at all times take appropriate steps to protect them from damage. If it is necessary to carry cables some distance from the machines, run the cables overhead, if possible, using adequate supporting devices.

SAFETY OF PERSONNEL

If it is necessary for a welding operator to work on platforms, scaffolds, or runways at an elevation of more than 5 feet, provisions should be made to prevent falling. This can be accomplished by the use of a railing or some other equally effective safeguard.

Helmets or hand shields should be used during all arc welding or arc cutting operations. Goggles should also be worn by personnel in the vicinity of arc welding or cutting operations to protect eyes from injurious rays from adjacent work and from flying objects. The goggles may have either clear glass or colored glass, depending on the amount of exposure to adjacent welding operations. Helpers or attendants should be provided with proper eye protection.

Goggles or other suitable protection should be used during all gas welding or oxygen cutting operations.

The specifications for protectors are as follows: